SURVEY NOTES

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UTAH GEOLOGICAL & MINERAL SURVEY

RADON

COLORLESS.
ODORLESS.
TASTELESS.

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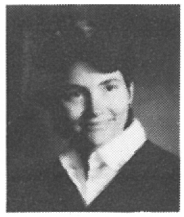

FROM THE DIRECTOR'S CORNER

This issue of *Survey Notes* highlights radon ... an odorless, colorless, rather insidious gas that emanates from soil and rocks virtually everywhere and which, when breathed in high concentrations, is a significant cause of lung cancer. Scientists agree that radon is a health problem but don't yet know at what concentrations it becomes a serious hazard or how to avoid the hazard.

Doug Sprinkel's *Survey Notes* lead article explains Utah's radon hazard as we know it today, and what the State and individuals are doing about it. Unlike most chemical hazards emitted into air or discharged into water, radon occurs naturally. As a constituent of earth's atmosphere, it was here long before man arrived. But our recognition of it and its risks are relatively recent. Radon infiltrates every home to some degree. Construction practices and, to an even greater extent, life style habits affect risk ... smoking and radon are a lethal combination.

The UGMS and other scientific organizations are faced with the problem of alerting society to the radon hazard before scientific research has provided an understanding of the hazard and reached consensus on the most effective ways to reduce the risk. Some information that has been released to the public has been criticized as misrepresenting the hazard and causing undue concern. Doug's article attempts to describe the radon hazard in Utah as it currently is understood, and also points out the gaps in our knowledge. His article also includes statements such as "work continues and more information becomes available ... the map can be used only as a guide ... not much is known about ..." etc. Bedrock characteristics, hydrology, and geologic structure appear to be significant factors controlling distribution of the hazard, and a better understanding of the hazard requires further research in geology, geochemistry and geophysics.

Scientists are faced with the dilemma, more so than with other geologic hazards, of translating technical information about radon hazards to laypeople even though they themselves don't entirely understand the geologic considerations. Radon's quasi-unpredictable distribution is compounded by the problem of making measurements that accurately reflect exposure to the hazard. For instance, radon concentrations fluctuate dramatically with weather conditions and may vary widely within an individual home. How can a short article present the risk in a simplified way that acknowledges the danger without overly alarming the public?

Recognition of the radon hazard is still in its infancy. It eludes easy delineation. Even highly "susceptible" areas include isolated low radon concentrations. As our knowledge of the geologic processes that control radon's distribution improve, the hazards map shown in this issue of *Survey Notes* will change, probably significantly.

SOCIETY'S RESPONSE

In some areas of the United States, society's initial response to the radon hazard, unlike its response to many other geologic hazards such as earthquakes or landslides, has been through banking and lending institutions that have incorporated radon inspections into property transactions, much like termite inspections. Apparently, the risk to property values motivates society even more effectively than exhortations about the health risk. Clearly, incorporating the expense of geologic hazards into the economy encourages individuals to personalize the risk and take actions to reduce it.

Continued on next page.

UGMS' ROLE

One of UGMS' primary goals is to identify Utah's geologic hazards. Another is to better understand Utah's geology. Radon provides excellent opportunities to do both at the same time because, as we come to understand the relationship of bedrock geology, surficial geology, geologic processes, hydrology, and geologic structure, it is as if we are solving several simultaneous equations, concurrently. For instance, radon emanates along active faults. At present, we use faults to delineate the radon hazard, but we also discover buried faults by determining patterns of radon concentrations.

Several UGMS geologists have varying degrees of interest and expertise in Utah's radon hazard. Doug Sprinkel has been UGMS' primary contact with Utah's Division of Environmental Health. Barry Solomon, a recent addition to UGMS, will specialize in determining the causal relationship of geology and hydrology to measured high radon concentration and will work with state and county health officials. In addition, UGMS' ongoing geologic mapping program continues to provide basic bedrock and surficial materials information as new areas of the state are mapped and to relate this information to geologic hazards, including radon. Clearly, there is much to be better understood ... the location of the hazard, the geologic processes that increase and decrease risk, the interaction of rock, soil, water, and geologic structures. As the radon hazard becomes better understood, so will UGMS' role and the net result will be a better understanding of Utah's geology as well as a better basis on which to reduce risk.

UGMS staff and other Utahns received awards for their "accomplishments in fostering the implementation of measures to reduce losses due to earthquakes in the state of Utah," on behalf of the Utah National Earthquake Hazards Reduction Program.

Palmer DePaulis, Mayor, Salt Lake City
Jerald S. Lyon, Deputy City Engineer, Dept. of Public Works, Salt Lake City

Mayor DePaulis' administration has been active in preparing the city for a damaging earthquake by commissioning studies to evaluate the seismic resistance of city buildings and funding strengthening/relocation where necessary. One example is the base isolation retrofit of the City-County building.

Jerry has headed up Mayor Depaulis' seismic upgrade program and has seen that seismic considerations are incorporated into all new construction and remodeling, begun the work of retrofiting critical facilities, and been instrumental in moving critical services (such as fire and police) to safer quarters.

Craig V. Nelson, Salt Lake County Planning
Mike Lowe, Davis County Planning
Robert M. Robison, Utah County Planning

The three Wasatch Front county geologists have been a major factor in facilitating the implementation of loss reduction measures through their close work with planners and local government officials. They have worked closely together and with the UGMS to ensure uniform approaches to loss reduction along the Wasatch Front, and maintained contacts with researchers to see that the most current information is used.

Wendy Hassibe, USGS
Janine Jarva, UGMS

As editors of the Wasatch Front Forum, Wendy and Janine have contributed to the dissemination of information which is so vital in implementing loss reduction measures. Both have spent much time and effort in soliciting contributions, tracking research, and maintaining the Forum as a useful vehicle for the transfer of timely information.

William R. Lund, UGMS

Bill has worked closely with Dave Schwartz, Mike Machette, Allan Nelson, and Steve Personius of the USGS in Wasatch fault trenching studies, and coordinated the joint UGMS/USGS trenching work of 1986 and subsequent joint trenching projects along the Wasatch fault. He handled logistical arrangements, organized field trips, and is presently organizing a program to publish the results. The field trips held to inform local government officials and the press of the results of the studies have contributed greatly toward their understanding of earthquake hazards and the science involved in assessing hazards.

Fred E. May, Utah CEM

Fred has been instrumental in implementing CEM's earthquake program through his advice to communities regarding hazards mitigation and his role as Utah's State Hazards Mitigation Officer. He is presently completing a handbook to aid local governments in assessing risks and estimating losses due to earthquakes.

Assessing the Radon Hazard in Utah

by
Douglas A. Sprinkel

INTRODUCTION

Most geologic hazards are the result of natural dynamic processes that continue to shape and alter the landscape. Many times these processes affect property and lives, as Utahns were recently reminded by the 1980s debris flows, debris floods, landslides, and rise of Great Salt Lake which together cost the citizens of Utah hundreds of millions of dollars. Some of these geologic hazards are peculiar to Utah because of the state's regional and geologic setting, and some are common throughout the country. Radon, a radioactive gas formerly thought of largely as an occupation health hazard among underground uranium miners, has now been found in many buildings throughout the country in higher concentrations than anticipated. The Environmental Protection Agency estimates about 5,000 to 20,000 Americans will die each year from lung cancer caused by long-term radon inhalation (EPA, 1986). This concern for the health consequences associated with long-term exposures to elevated indoor radon levels has prompted scientists and health officials to assess the radon hazard and determine the extent of the problem.

Everyone receives some low-level radiation generated from naturally occurring radioactive isotopes found in nearly all rocks, soils, and water. We are also subjected to a certain amount of cosmic radiation that penetrates the earth's protective atmosphere everyday. The amount and distribution of terrestrial and cosmic radiation vary with altitude and location, but it occurs throughout the environment in small quantities. The daily external and internal dose of natural radiation that the general population receives poses a low health threat.

Terrestrial concentrations of radioactive isotopes are not uniformly distributed in rocks and soils. Some areas have elevated levels of radioactivity because of the geology. Nero (1986) pointed out that scientists began discovering elevated levels of natural radiation in many areas of the world from measurements taken to monitor background radiation levels near nuclear power plant sites. Concern of the scientific community grew over the potential consequences of exposures to elevated levels of naturally occurring radioactive isotopes.

Discussions of exposure to natural radiation and its apparent health effects began in the early 1960s and continued into the 1980s (Adams and Lowder, 1964; Adams and others, 1972; Gesell and Lowder, 1980; Vohra and others, 1982). Nero (1986) also noted that an increasing awareness of an apparent health risk from exposure to elevated levels of indoor radon began in the mid-1970s as a result of research conducted in Sweden. Scientists were also becoming aware of the potential health risks associated with locating building sites on uranium or uraniferous phosphate mill tailings or using uranium tailings as back-fill materials (NCRP, 1984a). Still, most of the health concern for the general population was focused on the potential exposure to significant sources of radiation from nuclear power plants.

Scientists were recently reminded that certain rock types do significantly contribute to elevated indoor radon levels. In 1984, a worker at the Limerick nuclear power plant in Pennsylvania repeatedly set off the radiation alarms in the plant (Nero, 1986). The source of the radiation was found to be his radon-contaminated home in Boyertown, Pennsylvania, which has one of the highest recorded levels of indoor radon in the United States. This area of Pennsylvania is within a geologic province called the Reading Prong consisting of metamorphic rocks that happen to have above-average concentrations of uranium. These rocks were the source for the radon found in the worker's home (Smith and others, 1987). This revelation reinforced what some scientists suspected and prompted other investigators to reexamine areas of similar geologic units. Investigations have identified other rocks types that typically contain above-average concentrations of uranium (Phair and Gottfried, 1964; Richardson, 1964; Rogers, 1964; Heier and Carter, 1964; Otton, 1988). These rocks, such as black, organic-rich shales and granites, are now primary candidates as sources of elevated levels of radon. From preliminary work conducted in some states, the Environmental Protection Agency (EPA, press release August 1986 and August 1987) suggests that areas of the United States underlain by certain rock types (metamorphic rocks, granites, black shales) have a greater likelihood of having elevated levels of indoor radon than areas underlain by other rock types (figure 1). However, rock type alone doesn't always indicate the areas that have elevated levels of indoor radon. Other geologic considerations such as permeability and porosity of the soil, water saturation of soils and rocks, and ground water play a role in determining probable hazard areas. Non-geologic considerations such as weather conditions, building construction, construction materials, and life styles directly influence indoor radon levels. Understanding geologic and non-geologic components and how they interact with radon, and the short-lived radon decay products, will significantly contribute toward an increased ability to assess areas of Utah more likely to have elevated indoor radon levels.

Little is now known about the extent of indoor radon levels throughout Utah. However, indoor radon measurements collected within the past few years in limited areas suggest that certain localities in Utah may be susceptible to elevated levels (Woolf, 1987). Lafavore (1987) shows about 15% of homes tested in Utah exceeded the EPA action level (EPA measurement protocols are discussed later in this article) of 4 pCi/l (4 picocuries per liter of air). Other studies (Rogers, 1956, 1958; Tanner, 1964; Horton, 1985; Sprinkel, 1987) addressed only Utah's outdoor radon occurrences in soil and water, or identified the distribution of certain rock types that may contribute to an indoor radon problem. There are two concurrent strategies that guide investigators in their attempt to determine the magnitude of the potential radon hazard in Utah. They are (1) determine the distribution

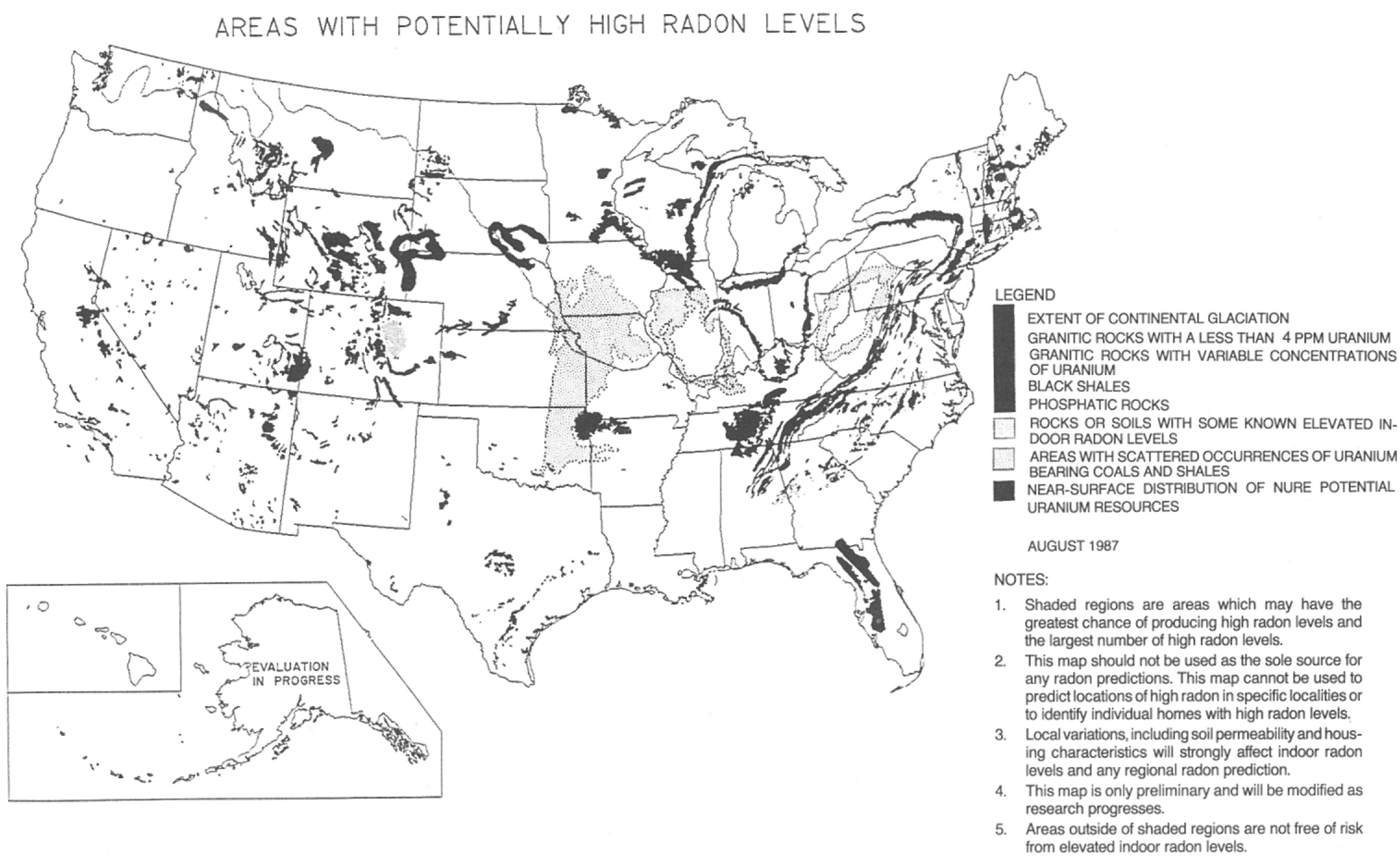

Figure 1. *Distribution of areas in the United States the Environmental Protection Agency (EPA) identifies with potential high radon levels. These areas delineate certain rock types [found throughout the U.S.] that have the capability of producing greater than average amounts of radon (EPA, press release August 1986 and August 1987).*

and magnitude of elevated indoor radon levels in existing buildings and (2) make geologic observations and develop methods to assess the likelihood of elevated indoor radon levels for undeveloped site-specific localities. Information gained from both approaches will supplement one another and provide a much clearer picture of the radon hazard in Utah.

RADON AS A HAZARD

Three questions commonly asked about radon as a hazard are (1) what is radon, (2) why is radon considered a hazard, and (3) why wasn't radon recognized as a hazard before now? To better understand radon as a potential hazard and the geologic factors that influence radon hazard assessments, a brief discussion of radon and radiation is necessary.

What is radon? Radon is an ordorless, tasteless, and colorless radioactive gas which forms in three radioactive series found in nature. The most common decay series where radon is present is the uranium (^{238}U) decay series where uranium decays to form stable lead (^{206}Pb) (figure 2). As new isotopes form through spontaneous disintegration they emit alpha, beta, and gamma radiation. Radon (^{222}Rn) is part of the uranium decay series and forms directly from the disintegration of radium (^{226}Ra). During radioactive decay a sequence of radon progeny forms. The radon progeny are short-lived radioactive products which mostly emit alpha and beta radiation (figure 2). Two other isotopes of radon (^{219}Rn and ^{220}Rn) occur in nature and may contribute to the indoor radon problem. For the purpose of this article the source of the potential hazard only includes radon (^{222}Rn) because it is the most abundant of the radon radioactive isotopes and it has the longest half-life of 3.825 days. Future references to radon in this article imply ^{222}Rn and the ^{238}U decay chain.

Radon occurs in nature and, similar to its parent isotopes radium and uranium, is found in nearly all rocks and soils in small concentrations. Most sources of radiation are solids. Radon is a gas that is generally chemically inert and very mobile. These characteristics give radon the ability to move with the air (or dissolved in water) through cracks and other open spaces in rocks and soils. Radon normally escapes into the atmosphere in small concentrations. However, large concentrations of radon may exist when favorable geologic conditions are present.

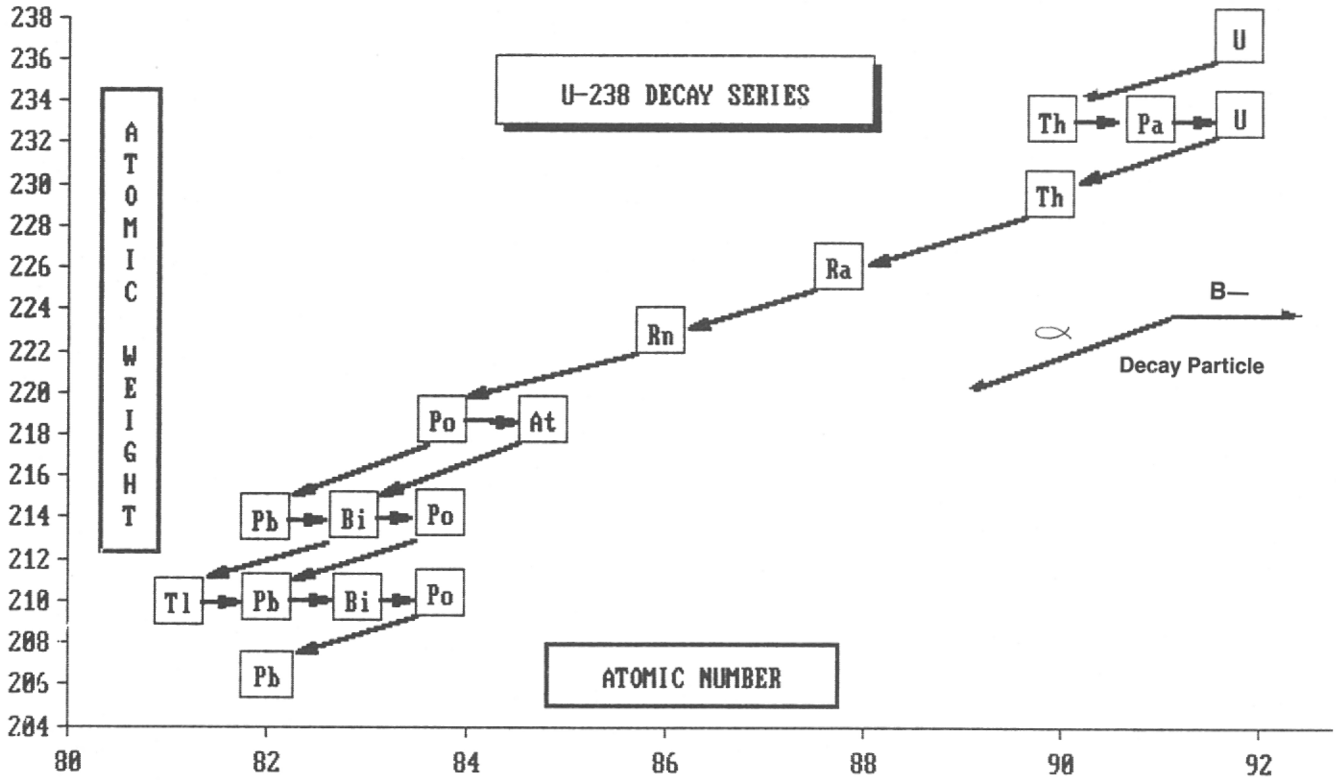

Figure 2. *Uranium (²³⁸U) decay series. Radon (²²²Rn) is derived from radium (²²⁶Ra) and is the only isotope in the series that is a gas. Because it is also inert, radon has the ability to move along with air or water (modified from Durrance, 1986).*

Why is radon considered a geologic hazard? Radon is a hazard because it is derived from geologic materials. In addition, geology influences local radon concentration, release, and migration. As mentioned earlier, radon and other sources of natural radiation occur most everywhere in small concentrations. Most of the natural background radiation a person receives daily is low-level external and internal doses that are not considered to be a general health threat. But health officials believe breathing elevated levels of radon over time increases the risk of inducing lung cancer because of the internal radiation to the lungs from decaying radon and radon progeny (Jacobi and Eisfeld, 1982; NCRP, 1984a, 1984b).

Radon concentrations in the atmosphere never reach dangerous levels because air movement dissipates the radon. People are more likely subjected to the risk of the radon hazard in buildings (homes, schools, office buildings) or natural enclosures with poor air circulation. The exposure to the hazard, in most cases, is dependent on non-geologic factors such as building condition and life styles.

Radon can find its way into buildings through small basement cracks or other foundation penetrations. It is in buildings, or other enclosures with poor air circulation, that radon can be trapped and begin to concentrate. Sextro (1988) cited a recent study by Nero and others (1985) which showed that nearly all homes tested in the United States contain some radon (figure 3). The EPA (1986) estimates the average indoor-radon concentration is about 1 pCi/l (1 picocurie per liter of air). Maximum radon concentrations are often in basement levels or low crawl spaces (Fleischer and others, 1982) because these parts of a house are in contact with the ground which is the primary source of radon and not because radon is denser than air. Still, indoor levels in most buildings generally are low.

Inhalation of radon alone is not thought to be the direct source of internal radiaiton because radon does not attach itself to the lining of the lungs. In addition, most of the inhaled radon atoms are exhaled before they decay and emit dangerous alpha particles to lung tissue. The radioactive isotopes formed from radon decay are of more concern because they are not inert and do readily attach themselves to the first charged surface they contact. In other words, the short-lived radon progeny produced from radon decay will become attached to the nearest particle in the air. Typically, these particles are common dust or smoke found in all homes. Households (or offices) with people who smoke place the occupants at greater risk because the home (or building) usually contains a greater percentage of particles in the air, which provides more opportunity for radon progeny to become attached than in smoke-free homes.

The dust or smoke particles with radon progeny attached

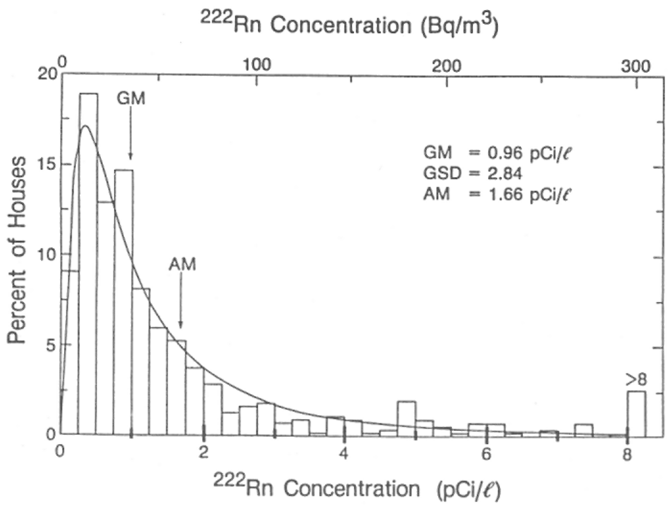

Figure 3. The actual distribution of radon concentrations in the U.S. is unknown, but this frequency distribution estimates the probable distribution of ^{222}Rn concentrations based on 552 U.S. homes surveyed. The smooth curve is a log normal function with the parameters shown. The geometric mean (GM) is about 0.9 pCi/l, the geometric standard deviation (GSD) is 2.8, and the average (AM) is 1.6 pCi/l (from Sextro, 1988).

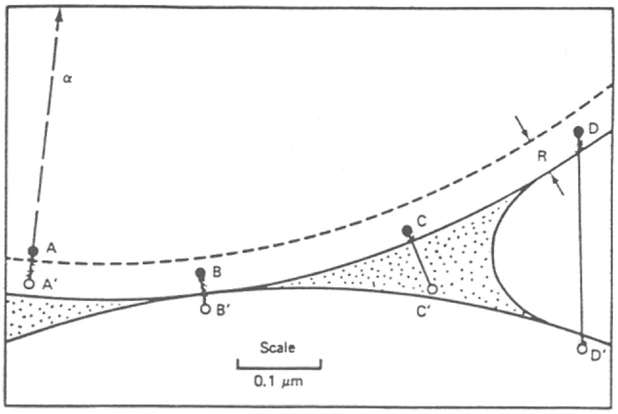

Figure 4. Idealized cross section of two grains and how radon can escape (the emanation process). The two grains are in contact near B. The stippled pattern represents a miniscus film of water between grains. The white area to the right of the water is air. Radium-226 atoms are represented by the solid dots and radon-222 atoms are the open circles. R is the recoil distance of the newly formed radon atom. Because of the small recoil distance of radon within the grain, only radium atoms found near the grain's surface would contribute to radon emanation. Recoiling radon atoms passing through a film of water are more likely to remain in the pore space, while radon atoms that pass only through air may become embedded in the adjoining grain and rendered harmless (from Tanner, 1980).

become lodged in the lining of the lungs when inhaled. Once lodged, the resident time in the lungs for these particles is greater than the cumulative half-life of the radon progeny. This allows tissue to be directly bombarded by a series of energetic alpha particles as the radon progeny decay (table 1).

Why has radon only recently received national attention as a hazard found in homes? Scientists had earlier suspected inhalation of radon and radon decay progeny as a health problem in the late 1950s and early 1960s when investigations were conducted on miners who worked in underground uranium mines. The studies concluded that high concentrations of radon found in underground uranium mines significantly contributed to an increased incidence of lung cancer among miners (NCRP, 1984b). What focused the attention of indoor radon to homes was the discovery in 1984 of high levels of radon within a home near Boyertown, Pennsylvania. Prior to that most scientists believed that indoor radon problems were associated with homes built on uranium mill tailings (NCRP, 1984a) or uraniferous phosphate processing waste. The lower concentrations of uranium (or radium) found in a variety of rocks were assumed not to contribute to significant levels of radon indoors. But the association of elevated indoor radon levels with the lower concentrations of uranium (or radium) found in various rocks, such as granites or black, organic-rich shales, was surprising. The potential for elevated levels of indoor radon are now associated with rock having average uranium concentrations less than 15 ppm (parts per million) (Durrance, 1986). Many areas of the country, including much of Utah, are underlain by rock which could be responsible for producing elevated indoor radon levels.

Changes in building practices over past 15 years have also contributed to the radon problem today. Since the 1973 oil embargo, conservation of our non-renewable energy resources has been a national goal through energy-efficient practices. The building industry has done an exceptional job of making structures more energy efficient. However, they have not improved adequate ventilation systems to accommodate for restricted natural air flow. Buildings, including single-family homes, constructed before 1973 often did not use energy-efficient measures, allowing indoor air to escape through above-grade joints, attic, and uninsulated walls. This amount of ventilation often prevented indoor radon levels rising to critical concentrations. Today, most homes are built with energy-efficient standards in place which prevents the loss of indoor air to the outside. Studies (Fleischer and others, 1982; Nero and others, 1982) have shown that energy-efficient buildings with under-designed ventilation systems generally have higher indoor radon levels compared with conventional buildings.

GEOLOGIC CONSIDERATIONS

For radon to be a problem it must build up to elevated concentrations within homes or buildings where people reside. Tanner (1986) suggested four ingredients must be met in order to have an indoor radon problem. The home (1) must be built on ground that contains radium, (2) has underlying soils that promote easy movement of radon, (3) has porous building materials or openings below grade, and (4) has lower atmospheric pressure inside. Thus, the ground must contain a certain amount of radium from which radon emanates. Radon has to travel easily through the soil to the structure before it decays. The structure must have foundation cracks or spaces in contact with the ground and have a lowered atmospheric pressure inside to allow radon to enter. Domestic water and home construction materials also contribute to indoor radon levels. However, the major contributor of radon, in most cases, is the geologic materials immediately underlying the home.

The first geologic consideration is the distribution of rocks that may contain uranium (or radium) in unusually high concentrations. Areas underlain by rock such as granite, metamorphic rocks, some volcanic rocks, and black, organic-rich shales (plus other sedimentary units) are generally associated with a potential indoor radon hazard. Later in this article the distribution of these rock types in Utah are discussed. If the radioactive source rock is present in the ground, there are several geologic considerations that enhance or impede radon emanation and movement. Most of these factors are observable and measurable in the field. The results of initial geologic work can be a foundation for understanding radon behavior for that particular geologic terrain and the impetus for more detailed investigations. Many of the principles and techniques used to detect radon emanation and migration were first developed for uranium exploration during the uranium boom three decades ago (IAEA, 1976). Radon hazard assessment uses the same principles and techniques but different levels of sensitivity.

Once radium is present in the mineral matter of the rock or soil, the radon formed must escape the crystal structure or surface films of the mineral grain. It does so during the spontaneous decay of radium where an alpha particle and a radon atom are given off. The radon atom recoils in the opposite direction of the alpha particle. Radon atoms near the grain's surface may recoil and end up in the pore or burrow into an adjacent mineral grain (figure 4). Because the newly produced radon atom has a small recoil distance, grain size, pore size, porosity, and moisture content are important components in radon emanating power (Tanner, 1964, 1980; Barretto, 1975). Emanating power is defined as the fraction of radon atoms that escape from the solid where they were formed (Tanner, 1980).

Tanner (1964, 1980) and Barretto (1975) discussed the inverse relationship between grain size and emanating power. Grains larger than 1 micron can retard radon recoil since the recoil distance is less than the grain size and radon atoms produced deep in the grain's interior are unlikely to escape. Only radon atoms near the grain's surface have the opportunity to escape, thus reducing the amount of available radon atoms. Tanner (1980) also points out that small pore size can reduce emanat-

Isotope	Symbol	Half-Life	Decay Particle	Energy (MeV)
Uranium	U-238	4.468 billion years	a	4.195 4.14
Thorium	Th-234	24.1 days	b	0.192 0.10
Protactinium	Pa-234m Pa-234	1.18 minutes 6.7 hours	b b	2.31 2.3
Uranium	U-234	248,000 years	a	4.768 4.717
Thorium	Th-230	80,000 years	a	4.682 4.615
Radium	Ra-226	1602 years	a	4.78 4.59
Radon	Rn-222	3.825 days	a	4.586
Polonium	Po-218	3.05 seconds	a, b	6.0
Astatine	At-218	2 seconds	a	6.7 6.65
Lead	Pb-214	26.8 minutes	b	0.7 1.03
Bismuth	Bi-214	19.7 minutes	a, b	a=5.5 b=3.2
Polonium	Po-214	0.000164 seconds	a	7.68
Thallium	Tl-210	1.32 minutes	b	5.43
Lead	Pb-210	22.3 years	b	0.015 0.061
Bismuth	Bi-210	5.02 days	a, b	a=4.7 b=1.16
Polonium	Po-210	138.3 days	a	5.3
Lead	Pb-206			

Table 1. *Uranium decay series showing the half-lives of isotopes. Radon's half-life is less than four days and the radon progeny combined half-life is about 90 minutes.*

a=alpha
b=beta

ing power because the recoiling radon can pass through the pore space and become embedded in the adjacent grain.

Another factor that influences radon production is the water that occupies the space between the grains. Tanner (1980) discussed the fact that a little water coating the grains can increase radon emanation. When radon recoils from the grain it can pass through a dry pore space and become imbedded in the adjoining grain and rendered harmless. However, if the grain has a thin coating of moisture, the moisture can absorb the recoil energy of the radon atom and the radon is more likely retained in the pore space. So moisture doesn't increase the rate of radon production, but it allows a higher percentage of recoiling radon atoms to remain in the pore space.

Once radon occupies the pore space of the rock or soil, it has the ability to move. Radon migration results from two mechanisms, diffusion and mass transport. It was once thought that most of the radon movement through the rock or soil column occurred by diffusion (the random movement of radon atoms by natural vibration). However, the distance radon can travel by diffusion in about four days is negligible (Barretto, 1975). Because measurements of high concentrations of radon in some areas are unaccountable by diffusion alone, Tanner (1964) suggests that mass transport of radon by the convective flow of soil gas is the primary mechanism to move large quantities of radon through the ground. Convective flow of soil gas is caused by air pressure differences within the soil, or between the soil and atmosphere, or between the soil and foundation of a structure. Air pressure differences can be caused by barometric pressure changes in the atmosphere, wind blowing across a surface, or thermal convection generated by heating or cooling. These processes go on in nature and affect the release of radon from the soil, however they also affect radon levels within a structure. Home heating and wind conditions can create localized low pressure inside a home, allowing it to be an effective pump drawing in underlying radon-laden soil gas. Recent discussions (Clements and Wilkening, 1974; Tanner, 1980) imply that both diffusion and flow are active in radon migration. However, one mechanism may dominate another at different times during migration.

Water saturation of soil or rock columns can effectively inhibit the migration of radon. A little water increases radon emanation; however, a lot of water restricts radon migration by reducing diffusion and blocking flow of soil gas (Tanner, 1980). Radon may move with the water, but the flow of water through soil and rocks is much slower. However, Tanner (1980) does note that water is an effective means to carry radon from its rock source. Where domestic water sources contain high levels of radon, they may contribute to indoor radon levels. Thermal waters and the deposits they derive (tufa) are also likely sources of radon.

Permeability and porosity of the rock or soil column influences radon's ability to get to the surface. There appears to be a correlation between areas that have permeable soils and elevated indoor radon concentrations (Tanner, 1980; Schery and Siegel, 1986). Measuring radon concentrations over large areas can also identify buried fault zones. Monitoring changes in radon concentrations on active fault zones, such as the San Andreas fault zone, or in volcanically active areas may serve as a possible indicator of future geologic activity such as earthquakes or volcanic eruptions (Tanner, 1980; King, 1986; Teng and Laing, 1986; Thomas and Cuff, 1986).

POTENTIAL RADON HAZARD AREAS IN UTAH

Not much is known about the location and distribution of indoor radon levels in Utah. However, there are several areas in Utah that may have the proper geologic setting for a radon hazard. Sprinkel (1987) mapped potential radon hazard areas in Utah. These areas were identified on the basis of distribution of known uranium occurrences (possible point sources for radon) and uranium-enriched rocks (generalized sources) found at the surface or beneath well-drained, porous and permeable soils. Uranium occurrences have been previously described by Hintze (1967), Doelling (1969), Chenoweth (1975), Silver and others (1980), Gurgel and others (1983), Stevens and Morris (1984). Included are uranium mines, uranium occurrences, uranium mill sites, geothermal and other thermal areas. Uranium-enriched rocks have been described by Durrance (1986). Distribution of these rock types (as well as other rock types) were mapped by Hintze (1980). Sprinkel (1987) did not include Quaternary units in the compilation unless reported in publication (Stevens and Morris, 1984), nor major fault zones as hazard areas.

Additional work has revealed other areas of Utah which are likely candidates for a radon hazard. This work (figure 5) includes the location of the Wasatch fault zone based on published geologic maps (Scott and Scroba, 1985; Davis, 1983a, 1983b, 1985; Personius, 1988). In addition, a map of apparent surface concentration of uranium (Joseph S. Duvall, unpublished map, 1987) outlines the distribution of uraniferous rocks not shown by geologic mapping.

Figure 5 represents a composite map showing areas in Utah currently thought to have a greater chance of having a radon hazard based on geologic data. It is only a guide to help state health officials, interested decision-makers, developers, and the public determine areas for indoor radon measurements. The patterned areas primarily represent generalized outcrop patterns. The boundaries of these areas are imprecise and may change with future, detailed, study. Non-patterned areas between closely grouped patterned areas may eventually fill in, forming belts of generalized sources. Areas of low radon potential may occur within patterned areas. As work continues and more information becomes available, modifications to radon hazard areas depicted on the map (figure 5) are inevitable. It is important to remember that this map only addresses some of the geologic considerations that influence the location of the indoor radon hazard. Other considerations such as movement of radon through soil, permeability, condition of the building foundation, and lower indoor atmospheric pressure are not represented.

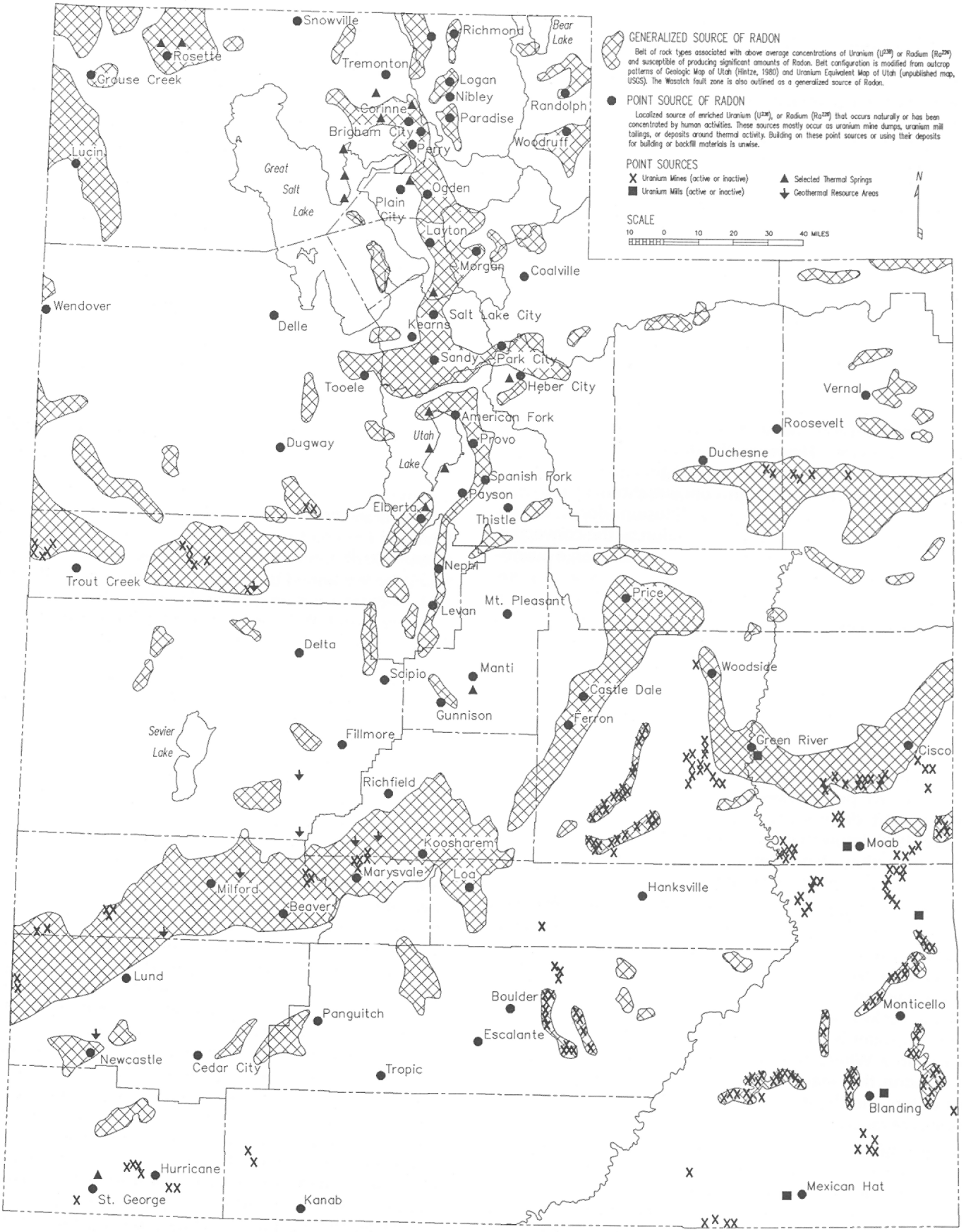

Figure 5. *Generalized radon potential map of Utah (modified from Sprinkel, 1987).*

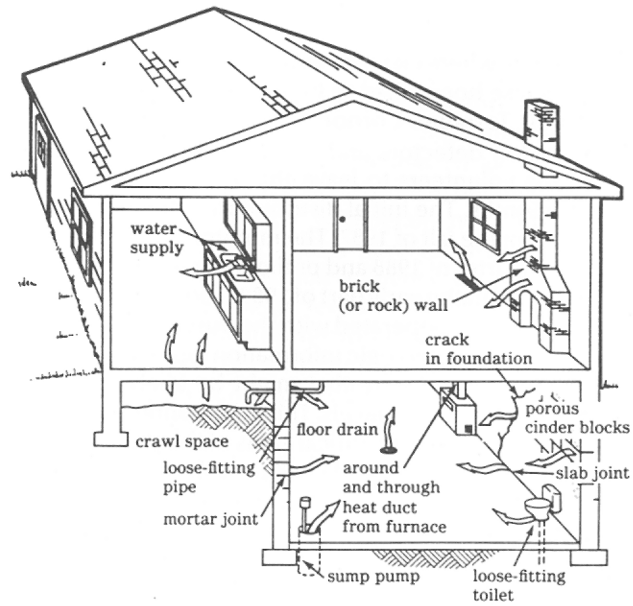

Figure 6. *Various pathways for radon to enter a home. Most of the entry routes are in the basement, since that's the part of the house with the greatest surface area exposed to the surrounding soil. The most common pathways are through cracks and spaces around pipes, sump holes, floor drains, and the joint between the floor and walls. The gas can also enter the house dissolved in the water (reprinted from* Radon: The Invisible Threat© *by Michael Lafavore. Permission granted by Rodale Press, Inc., Emmaus, PA 18049.*

DETERMINING INDOOR RADON LEVELS

Even though a building (or home) is within an area identified as being a potential radon hazard, it may not have an elevated level of indoor radon. Conversely, a building located in an area with no obvious geologic indicators may have high indoor radon levels. Non-geological factors, such as foundation condition, building ventilation, building material used, life styles, etc. influence indoor radon levels. However, average indoor radon levels in areas where favorable geologic conditions exist are consistently higher than other areas. As discussed earlier, the primary source of most radon found in a building generally comes from the underlying geologic materials. The radon enters the building through below-grade foundation cracks or penetrations, such as utility pipes (figure 6). Because of the influence of non-geologic factors on indoor radon concentrations, presently the most conclusive means to determine if a specific building has a radon problem is to measure radon concentrations in the building. There are several methods to measure radon. They include short-term and long-term passive detectors and electronic instruments. Some may be placed by the homeowner, others require a private company. Most people want to have information quickly so they often select short-term monitoring which gives quick, accurate results. However, long-term monitoring may provide more realistic information and may prevent unnecessary costly modifications to the building.

Measurements taken over a few days or on single day will provide only a snapshot of indoor radon levels for that particular time. Radon concentrations in the ground fluctuate daily, weekly, and monthly because of meteoric changes (Kramer and others, 1964; Schery and Gaeddert, 1982). Indoor radon levels also respond to changing weather conditions. In addition, concentrations can fluctuate seasonally because buildings are more closed up in the winter than summer. Indoor heating and air conditioning also affect concentrations. A longer period of monitoring (twelve month period) is generally recommended to smooth out short-term fluctuations. This will provide a more realistic picture of the yearly average indoor radon concentration for that building. Ronca-Battista (1988) discussed radon measurement protocols suggested by the Environmental Protection Agency to assure accuracy and consistency of data. They were developed to balance the need to obtain results quickly and acquire the best possible measurement which best reflects the long-term indoor radon levels. Ronca-Battista (1988) also indicates that a short-term measurement is any test conducted less than three months regardless of the type of detector used. The Utah Bureau of Radiation Control in Salt Lake City provides specific information on the different types of radon detectors available, their advantages and disadvantages, and comparative cost.

Most buildings throughout the United States will contain some radon, but concentrations are usually less than 3 pCi/l (3 picocuries per liter of air). Long-term exposure to these levels are generally considered a small health risk to the general population. Figure 7 shows the risk posed by various levels of radon. A picocurie (pCi) is the decay of about 2 radon atoms per minute. Thus 10 pCi/l represent the decay of about 22 radon atoms per minute in one liter (about one quart) of air. Another unit of measurement often used to report concentrations are working levels (WL). This is different from a picocurie because it is a unit of measurement of radon decay product concentrations. One working level (WL) is defined as the quantity of short-lived radon decay products that will result in 1.3×10^{-5} Mev (million electron volts) of potential alpha energy per liter of air (EPA, 1987).

To determine, as accurately as possible, the indoor radon levels throughout the home, long-term monitoring is needed on each floor. EPA (1986) and Ronca-Battista (1988) suggest, however, that a short-term screening measurement which follows EPA protocol (closed-house conditions) may be conducted in the lowest livable area of the house to determine if additional or follow-up testing is necessary. According to EPA (1986) additonal testing is not needed if the short-term screening measurement is less than 4 pCi/l and, although a small health risk is present, remediation is unnecessary. If a result is greater than 4pCi/l and less than 20 pCi/l, a follow-up test of a 12-month measurement in two living areas of the house is recommended by EPA (1986). If retesting confirms screening measurements, mitigation may be warranted in a few years. If a screening measurement is greater than 20 pCi/l and less than 200 pCi/l, retesting is recommended in two living areas of the house for no more than three months (EPA, 1986). If a screening measurement is confirmed, remediation should take place within the next several months. If a screening measurement is over 200 pCi/l, retest immediately in at least two living areas of the house (EPA, 1986). If confirmed, remedial action should

Figure 7. *Radon risk evaluation chart. Different people perceive their risk to geologic hazards differently. The EPA has developed this chart to provide comparable risks for people to evaluate their personal risk to the radon hazard (EPA, 1986).*

Radon Risk Evaluation Chart

pCi/l	WL	Estimated number of lung cancer deaths due to radon exposure (out of 1000)	Comparable exposure levels		Comparable risk
200	1	440—770	1000 times average outdoor level		More than 60 times non-smoker risk
100	0.5	270—630	100 times average indoor level		4 pack-a-day smoker
40	0.2	120—380			20,000 chest x-rays per year
20	0.1	60—210	100 times average outdoor level		2 pack-a-day smoker
10	0.05	30—120	10 times average indoor level		1 pack-a-day smoker
4	0.02	13—50			5 times non-smoker risk
2	0.01	7—30	10 times average outdoor level		200 chest x-rays per year
1	0.005	3—13	Average indoor level		Non-smoker risk of dying from lung cancer
0.2	0.001	1—3	Average outdoor level		20 chest x-rays per year

EPA, 1986 OPA 86-004 Fig. 6

commence within several weeks. Similarly, the Utah Bureau of Radiation Control follows these guidelines but emphasizes the value in long-term monitoring (D. Finerfrock, personal comm., 1987). Ronca-Battista (1988) recently outlined current EPA measurement protocols. They appear to emphasize immediate short-term, follow-up testing in two living areas of homes with screening measurements greater than 20 pCi/l.

CURRENT PROGRAMS ASSESSING THE POTENTIAL RADON IN UTAH

The Utah Bureau of Radiation Control, an agency within the Department of Environmental Health, is conducting a survey to assess indoor radon levels statewide. The study involves the participation of about 750 volunteers in several cities throughout the state where elevated indoor radon levels are thought to occur. These homes had to be owner-occupied single-family dwellings. Terradex Corporation provided the Alpha Track-Etch© radon detectors and the Bureau of Radiation Control asked the volunteers to leave the device in their homes for twelve months. The initial distribution of the radon detectors occurred in the fall of 1987. The monitoring period will end in the final quarter of 1988 and preliminary survey results should be compiled in the early part of 1989. The Utah Geological and Mineral Survey cooperated with the Bureau of Radiation Control by providing geologic information (Sprinkel, 1987) to help select areas in the state that might be likely candidates for elevated indoor radon levels. This information was the basis for soliciting volunteers in critical areas of the state. The information derived from this study will provide state health officials with the first indication of the extent of Utah's indoor radon problem. The study will also provide the Utah Geological and Mineral Survey with valuable information required to examine the relationships between geology and indoor radon levels.

The Utah Geological and Mineral Survey believes that conducting a statewide survey is essential in understanding the potential extent of an indoor radon problem. The Utah Geological and Mineral Survey is also interested in determining methods to geologically characterize an area for potential radon problems and produce usable information for health officials, decision makers, developers, and the general public. Our cooperation with the Bureau of radiation Control is an important part of that goal. Additionally, the Utah Geological and Mineral Survey, in cooperation with the University of Utah Research Institute is conducting an investigation on Antelope Island to add to the understanding of the geologic factors that influence radon occurrence, emanation, and migration. Antelope Island was selected because detailed geologic mapping (Doelling and others, 1988) is available and it consists of a variety of metamorphic, igneous, and sedimentary rocks that have been structurally complicated. Understanding the potential radon hazard of Antelope Island will hopefully aid in any future site selection of permanent island residences. The geology on the island is similar in some respects to that of the Davis and Weber Counties and this study will also aid in the greater understanding of potential radon hazard of this part of the highly populated Wasatch Front urban corridor.

SUMMARY

Radon is a new environmental concern throughout the country because of its suspected link to lung cancer. Radon is an odorless, tasteless, and colorless radioactive gas that occurs in nearly all rocks and soils. It is found in most buildings in small enough concentrations that it is generally not considered a health threat. However, scientists have recently discovered certain geologic conditions that influence the likelihood of having elevated indoor radon levels in buildings. Because of the complex relationships between geologic and non-geologic factors that control radon levels, predicting radon concentrations from building to building is difficult. The current understanding of radon behavior prohibits extrapolating radon values over any distance. But with additional indoor radon surveys and geologic characterization of sites, discovering critical combination of components will lead to an easier and reliable radon assessment. It is important to assess indoor radon levels in Utah and determine the extent of the problem statewide. It also is equally important to determine the critical factors that contribute to the potential radon hazard of an undeveloped area. The use of that information by health officials, decision-makers, developers, and the public may facilitate mitigation techniques into building design before developing an area.

ACKNOWLEDGEMENTS

Understanding radon as a hazard is complex and integrates several scientific disciplines including geology, physics, chemistry, and health physics. I am greatful to the scientists who, through discussions, provided valuable insight into the various aspects of radon. I thank Hellmut H. Doelling (UGMS) and Don R. Mabey (formerly UGMS, USGS) for technically reviewing the Generalized Radon Potential Map of Utah. Their suggestions were extremely beneficial in developing the map. I am also indebted to the following for taking time to review this manuscript; their efforts are appreciated and significantly improved this paper. They include Dane Finerfrock, Utah Research Institute; Miriam H. Bugden, Utah Geological and Mineral Survey; John S. Hand, Utah Geological and Mineral Survey; and Genevieve Atwood, Utah Geological and Mineral Survey. I would like to especially thank James K. Otton of the U.S. Geological Survey for taking the time to review this manuscript, for his guidance and suggestions were particularly helpful.

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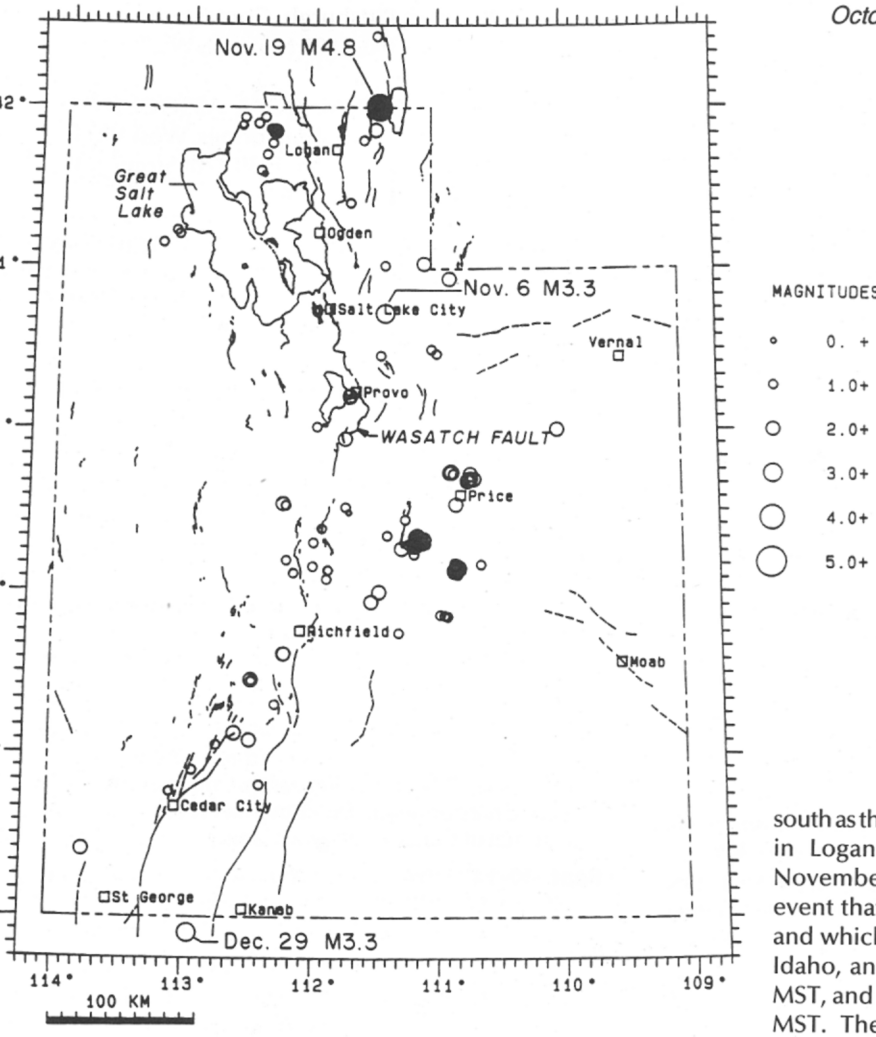
Utah Earthquake Activity

by Susan J. Nava
University of Utah Seismograph Stations, Department of Geology and Geophysics

October 1 — December 31, 1988



During the three-month period October 1 through December 31, 1988, the University of Utah Seismograph Stations located 245 earthquakes within the Utah region (see accompanying epicenter map). Of these earthquakes, 80 had a magnitude (either local magnitude, M_L, or coda magnitude, M_C) of 2.0 or greater, five had a magnitude of 3.0 or greater, and six were reported felt.

The largest earthquake during the report period was a shock of M_L 4.8 on November 19 at 12:42 PM MST on the Utah-Idaho border, 5 km west of Bear Lake, in northern Rich County. The Bear Lake earthquake was felt widely in northern Utah and southern Idaho (Modified Mercalli Intensity IV to V), and as far south as the Salt Lake Valley. Minor damage was reported in Logan and Ogden, Utah. Aftershocks of the November 19 Bear Lake earthquake include an M_L 4.3 event that occurred 18 minutes after the main shock and which was felt in northern Utah and in southern Idaho, an M_L 3.2 shock on November 28 at 3:46 AM MST, and an M_L 2.8 shock on December 2 at 11:46 AM MST. The latter two were felt by residents in nearby small towns. During the report period, 50 earthquakes associated with the Bear Lake sequence have been located.

Two other earthquakes of magnitude 3.0 and greater occurred in the Utah region during the report period: one of M_L 3.3 on November 6 at 8:30 AM MST, located 9 km NNE of Park City, Utah, and reported felt as far away as the Salt Lake Valley; and another of M_C 3.3 on December 29 at 11:18 AM MST, located 40 km SW of Kanab, Utah. One additional earthquake was reported felt in Utah during the report period: an M_L 1.8 event on October 28 at 4:10 PM MDT, felt in West Valley City.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations.

Geo-Calendar

Meeting information is as accurate as we can make it. Listings may be sent to Survey Notes Editor, *but we're picky.*

Apr. 6-7 GSA SOUTHEASTERN SECTION MEETING in Atlanta. Contact J.A. Whitney, Dept. of Geology, University of Georgia, Atlanta, GA 30602, (404) 542-2652.

Apr. 5-7 SOCIETY OF PETROLEUM ENGINEERS REGIONAL MEETING, Bakersfield, CA. Contact SPE, Box 833836, Richardson, TX 75083-3836. (214) 669-3377.

April 7 FIBERS, FIBERS, FIBERS, sponsored by Society of Mining Engineers in Baltimore, MD. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162. (303) 973-9550.

Apr. 20-21 GSA NORTH-CENTRAL SECTION meeting in Notre Dame. Contact Michael J. Murphy, Dept. of Earth Sciences, Univ. of Notre Dame, Notre Dame, IN 46556, (219) 239-6686.

Apr. 23-26 AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS 74TH ANNUAL CONVENTION, San Antonio, TX. Contact AAPG, Box 979, 1444 S. Boulder, Tulsa, OK 74101. (918) 584-2555.

May 3-5 CALIFORNIA MINING ASSOCIATION ANNUAL MEETING AND INDUSTRY EXHIBITS, in Sacramento. Contact California Mining Association, 1010 11th Street, Suite 213, Sacramento, CA 95814, (916) 447-1977.

May 3-5 WESTERN SURFACE COAL MINING MEETING, Gillette, Wyoming. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO.

May 7-10 ROCKY MOUNTAIN AND CORDILLERAN SECTIONS, GSA JOINT MEETING held in Spokane, WA. Contact Sandra Rush, GSA Communications Dept., P.O. Box 9140, 3300 Penrose Place, Boulder CO 80301; (303) 443-8489.

May 20-24 FOURTH U.S. NATIONAL CONFERENCE ON EARTHQUAKE ENGINEERING, in Palm Springs, CA. Contact Dee Czaja, 4NCEE, Civil Engineering Dept., Univ. of California, Irvine, CA 92717, (714) 856-8693.

June 5-7 INTERNATIONAL GOLD-SILVER CONFERENCE IX, in Sparks, Nevada. Contact Dr. Yung Sam Kim, Nevada Institute of Technology, P.O. Box 8894, Reno, NV 89507, (702) 331-0607.

June 8-10 ELKO MINING EXPO '89 at the Elko Convention Center in Elko, NV. Contact: Kay Thompson, Elko Convention and Visitors Authority, 700 Moren Way, Elko, Nevada 89801. Phone 1-800-248-ELKO.

June 11-15 RAPID EXCAVATION AND TUNNELING, sponsored by the Society of Mining Engineers, at the Bonaventure Hotel in Los Angeles. Contact: Darline Daley, Society of Mining Engineers, P.O. Box 625002, Littleton, CO 80162. (303) 973-9550.

June 15-16 WYOMING MINING ASSOCIATION CONVENTION in Rock Springs. Contact: Wyoming Mining Association, Hitching Post Inn, P.O. Box 866, Cheyenne, Wyoming 82001. Phone (307) 635-0331.

June 19-22 AMERICAN MINING CONGRESS COAL CONVENTION '89 in Pittsburgh. Contact: the American Mining Congress, Suite 300, 1920 N Street, Washington, DC 20036. (202) 861-2821.

June 22-25 NATIONAL COAL ASSOCIATION ANNUAL MEETING in White Sulphur Springs, West Virginia. Contact: National Coal Association, 1130 17th Street N.W., Washington, DC 20036. (202) 463-2625.

July 9-19 28TH INTERNATIONAL GEOLOGICAL CONGRESS, Washington, D.C. For information contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001, (703) 648-6053.

July 30-Aug. 2 SOIL AND WATER CONSERVATION SOCIETY 44TH ANNUAL MEETING in Edmonton, Alberta, Canada. Contact Alfred Birch, 7515 N.E. Ankeny Road, Ankeny, IA 50021.

Aug. 13-23 FRIENDS OF THE PLEISTOCENE, ROCKY MOUNTAIN CELL, 1989 FALL FIELD TRIP. Contact Pete Birkeland, Dept. Geological Sciences, Campus Box 250, Univ. of Colorado, Boulder, CO 80309.

Sept. 7-9 INTERNATIONAL GOLD EXPO, sponsored by the Engineering and Mining Journal, at Bally's Convention Center in Reno. Contact: Industrial Presentations, Inc. 12371 East Cornell Avenue, Aurora, CO 80014. (303) 696-6100.

Sept. 10-14 EDITING INTO THE NINETIES. Joint meeting at the Westin Hotel in Ottawa, Canada of Council of Biology Editors, European Assn. of Science Editors, Assn. of Earth Science Editors, and National Research Council of Canada. Contact Ken Charbonneau, Executive secretary, National research Council of Canada, Ottawa, Canada K1A OR 6, (613) 993-9009.

Sept. 10-14 WYOMING GEOLOGICAL ASSOCIATION 40TH FIELD CONFERENCE. Contact Lynette George, 2220 Volcaro Rd., Casper WY 82604 (307) 265-0775 or Stephen Hollis, PO Box 1068, Casper WY 82602 (307) 577-7460.

Sept. 25-28 SIAM CONFERENCE ON MATHEMATICAL AND COMPUTATIONAL ISSUES IN GEOPHYSICAL FLUID AND SOLID MECHANICS in Houston. Contact SIAM, 14th Floor, 117 So. 17th St., Philadelphia, PA 19103. (215) 564-2929.

Oct. 1-6 ASSOCIATION OF ENGINEERING GEOLOGISTS ANNUAL MEETING, Vail, CO. Contact Denver Section, AEG, P.O. Box 15124, Denver CO 80215.

Oct. 23-26 FOURTH INTERNATIONAL CONFERENCE ON SOIL DYNAMICS AND EARTHQUAKE ENGINEERING, in Mexico City, Mexico. Contact A.S. Cakmak, Dept. of Civil Engineering, Princeton University, Princeton, NJ 08544, (609) 452-4601.

Nov. 6-9 GSA ANNUAL MEETING in St. Louis. Contact Sandra Rush, GSA Communications Dept., 3300 Penrose Place, Box 9140, Boulder, CO 80301, (303) 447-8850.

UGMS Publications for 1988

Released from January 1 to December 30, 1988

MAPS

43 *Physiographic subdivisions of Utah,* by W.L. Stokes, 1 pl., 1:2,500,000, 1977 (reprint).

94 *Geologic map of the Pigeon Mountain quadrangle, Box Elder County, Utah,* by L.L. Glick and D.M. Miller, 1:24,000, 9 p., 2 pl, 1987.

95 *Geologic map of the Jackson quadrangle, Box Elder County, Utah,* by D.M. Miller and L.L. Glick, 1:24,000, 7 p., 2 pl., 1987.

103 *Geologic map of the Panguitch NW quadrangle, Iron and Garfield Counties, Utah,* by J.J. Anderson and P.D. Rowley, 1:24,000, 11 p., 2 pl., 1987.

104 *Geologic map of the Little Creek Peak quadrangle, Garfield and Iron Counties, Utah,* by J.J. Anderson T.A. livari, and P.D. Rowley; 1:24,000, 11 p., 2 pl., 1987.

105 *Geologic map of the Marysvale quadrangle, Piute County, Utah,* by P.D. Rowley, C.G. Cunningham, T.A. Steven, H.H. Mehnert, and C.W. Naeser, 1:24,000, 15 p., 2 pl., 1988.

106 *Geologic map of the Antelope Range quadrangle, Sevier and Piute Counties, Utah,* by P.D. Rowley, C.G. Cunningham, T.A. Steven, H.H. Mehnert, and C.W. Naeser, 1:24,000, 14 p., 2 pl., 1988.

108 *Geologic map of the Silver Peak quadrangle, Iron County, Utah,* by M.A. Shubat and M.A. Siders, 1:24,000 13 p., 2 pl., 1988.

110 *Shallow ground water and related hazards in Utah,* compiled by Suzanne Hecker and K.M. Harty, 1:750,000, 17 p., 1 pl., 1988.

111 *Flood hazards from lakes and failures of dams in Utah,* by Kimm M. Harty and Gary E. Christenson, 8 p., 1 pl., 1:750,000, 1988.

55-D *Mineral resources of the southern Wasatch Front, Utah,* compiled by Fitzhugh D. Davis with a section on petroleum by F.C. Moulton and R. L. Kerns, 17 p., 2 pl., 1:100,000, 1988.

55-C *Ground-water resources of the southern Wasatch Front, Utah* compiled by Don Price and L.S. Conroy, 6 p., 3 pl., 1:100,000, 1988.

MISCELLANEOUS PUBLICATIONS

87-2 *Mineral fuels and associated energy resources,* by M.R. Smith, flyer.

87-4 *Industrial Commodities: non-metallic resources of Utah,* by M.R. Smith, flyer.

S *Geology of Utah,* by W.L. Stokes, 305 p., 1986 (reprint).

88-1 *In the footsteps of G.K. Gilbert — Lake Bonneville and neotectonics of the eastern Basin and Range province,* edited by Michael N. Machette, 120 p., 1988.

88-2 *Geology and Antelope Island State Park, Utah,* by H.H. Doelling and others, 20 p., 1988.

88-3 *Geologic consequences of the 1983 wet year in Utah,* by B.N. Kaliser and J.E. Slossen, 109 p., 1988.

CIRCULARS

80 *Annual production and distribution of coal in Utah, 1987,* by A.D. Smith and F.R. Jahanbani, 8 p., 1988.

79 *Suggested approach to geologic hazards ordinances in Utah,* by G.E. Christenson, 16 p., 1987 (reprint).

BULLETINS

122 *Salt deformation in the Paradox region,* by H.H. Doelling, C. G. Oviatt, and P.W. Huntoon, 93 p., 1988.

125 *Geology and mineral potential of the Antelope Range Mining District, Iron County, Utah,* by M.A. Shubat and W.S. McIntosh, 26 p., 2 pl., 1988.

REPORTS OF INVESTIGATION

209 *Scandium-bearing aluminum phosphate deposits of Utah,* by M.A. Shubat, 26 p., 1988.

216 *Technical reports for 1987—Site Investigation Section,* compiled by B.D. Black, 115 p., 1988.

217 *An overview of landslide inventories predominantly in North America,* by Sandra Eldredge, 98 p., 1988.

218 *Technical reports of the Wasatch Front geologists, June 1985-June 1988,* compiled by B.D. Black and G.E. Christenson, 154 p., 1988.

OPEN-FILE REPORTS

82DF *Significant drill-hole data of the Wasatch Front valleys, including Cache Valley and Tooele Valley, Utah,* by W.F. Case and C.D. Burt, 27 p., 1 diskette, 1988.

108 *Potential radon hazard map of Utah,* by D.A. Sprinkel, 3 p., 1:1,000,000, 1987 (revised to September, 1988).

115 *Earthquake response strategies for UGMS and the earth-science community,* by G. Atwood, M. Noonan, W. Case, and D. Mabey, 33 p.

116 *Geology of the Boulder Mountain quadrangle, Cache County, Utah,* by A.R. Mork, 29 p., 2 pl., scale 1:24,000.

117 *Great Salt Lake brine sampling program 1985-1987,* by J. Wallace Gwynn, 30 p., 1988.

118 *Geology of the Gold Hill quadrangle, Tooele County, Utah,* by Jamie Robinson, 33 p., 1 pl., scale 1:24,000.

119 *Geology of the Geyser Peak quadrangle, Sevier County, Utah,* by S.T. Nelson, 37 p., 2 pl., scale 1:24,000.

120 *Geology of the Levan quadrangle, Juab County, Utah,* by W.L. Auby, 56 p., 2 pl., scale 1:24,000.

Continued on next page.

121 *Geology of the Calf Creek quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 21 p., 2 pl., scale 1:24,000.

122 *Geology of the Juab quadrangle, Juab County, Utah,* by D.L. Clark, 54 p., 2 pl., scale 1:24,000.

123 *Geology of the King Bench quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 14 p., 2 pl., scale 1:24,000.

124 *Geology of the Tenmile Flat quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 18 p., 2 pl., scale 1:24,000.

125 *Geology of the Red Breaks quadrangle, Garfield County, Utah* by G.W. Weir and L.S. Beard, 18 p., 2 pl., scale 1:24,000.

126 *Geology of the Fountain Green North quadrangle, Sanpete and Juab Counties, Utah,* by R.L. Banks, 78 p., 3 pl., 1:24,000.

127 *Maximum extent of potential flooding due to simultaneous failure of dams in Salt Lake County, Utah,* by W.F. Case, 28 p., 1 pl., 1" = approximately 1 ¼ miles, 1988.

128 *Quaternary geology of the Black Rock Desert, Millard County, Utah,* by C.G. Oviatt, 53 p., 1 pl., 1:100,000.

129 *Causes of shallow ground-water problems in part of Spanish Valley, Grand County, Utah,* by Robert H. Klauk, 46 p., 1988.

130 *Geologic map of the Antelope Peak quadrangle, Iron County, Utah,* by S.K. Grant and P.D. Proctor, 32 p., 1 pl., 1:24,000.

131 *Sample Library catalog,* by UGMS staff, 374 p.

132 *Acid neutralizing capacity map of Utah,* by William F. Case, 9 p., 1 pl., scale 1:500,000, 1988.

133 *West-central Kane County state lands evaluations for State Lands and Forestry,* by Hellmut H. Doelling, 517 p., 1988.

134 *Geology of the Tule Valley, Utah 30 x 60-minute quadrangle,* by Lehi F. Hintze and Fitzhugh D. Davis, 1 pl.

135 *Thematic mapping applied to hazards reduction, Davis County, Utah,* by B.N. Kaliser, 18 p., 1988.

136 *Preliminary geology of the Red Knolls quadrangle, Millard Co., Utah, by L.F. Hintze and F.D. Davis, 12 p., 1 pl.*

137 *Preliminary geology of the Long Ridge quadrangle, Box Elder Co., Utah,* by L.F. Hintze and F.D. Davis, 11 p., 1 pl.

138 *Geology of the Crater Island quadrangle, Box Elder Co., Utah,* by D.M. Miller, T.E. Jordan, and R.W. Allmendinger, 59 p., 1 pl.

139 *Geology of the Lucin 4 SW quadrangle, Box Elder Co., Utah,* by D.M. Miller, 45 p., 1 pl.

140 *Geology of Calico Peak quadrangle, Kane Co., Utah,* by H.H. Doelling and F.D. Davis, 40 p., 1 pl.

141 Geology of Lampo Junction quadrangle, Box Elder Co., Utah, by D.M. Miller, M.D. Crittenden, Jr., and T.E. Jordan, 49 p., 2 pl.

142 *Geology of the Cannonville quadrangle, Kane and Garfield Counties, Utah,* by R. Hereford, 25 p., 1 pl.

143 *Quaternary geology — Tule Valley, west-central Utah,* by D. Sack, 60 p., 1 pl.

144 *Geology of Antelope Island, Davis County, Utah,* by H.H. Doelling and others, 99 p., 2 pl., 1988.

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SURVEY NOTES
Winter 1987, Volume 21, No. 4

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number 1 & 2

Status of the Utah Geological and Mineral Survey, 1988 by Genevieve Atwood.
Rockfall in Hackberry Canyon, April 1988 by H.H. Doelling.
Geologic effects of the 14 and 18 August 1988 earthquakes in Emery County, Utah by W.F. Case.
The magnitude 5.3 San Rafael Swell, Utah earthquake of August 14, 1988; a preliminary seismological summary by S.J. Nava, J.C. Pechmann, and W.J. Arabasz.
CEM ALERT report summary of August 14, 1988 earthquake in Emery County by Jim Tingey and Fred May.
Utah earthquake activity by J.C. Pechmann.

number 3

The Wasatch fault zone, earthquakes and Salt Lake City: G.K. Gilbert to the present by W.R. Lund.
Utah earthquake activity by S.J. Nava.
UGMS Projects

number 4

Assessing the radon hazard in Utah by D.A. Sprinkel.
Mineral lease special projects program by D.A. Sprinkel.
Utah earthquake activity by S.J. Nava.

Books & Papers

Pay Dirt is a monthly mining magazine meticulously melded from two publications: *Rocky Mountain Pay Dirt* and *Southwestern Pay Dirt.* The former covers Montana, Idaho, Wyoming, Nevada, Utah, and Colorado and tries to cover all the pertinent mining news of interest. If you have an interest in mining, contact Pay Dirt, P.O. Drawer 48, Bisbee, AZ 85603

Annual production and distribution of coal in Utah, 1987, by A.D. Smith and F.R. Jahanbani, 8 p., 1988, UGMS Circular 80. Most of Utah's coal resources are located in the southern and central parts of the state. This circular is a brief summary of the 1987 coal production by county, coal field, and land ownership. It lists historical production from 1980 through the 1988 forecast, and charts the distribution and use of Utah coal, coal imports, exports, and future outlook.

Potential radon hazard map of Utah, by D.A. Sprinkel, 4 p., 1 pl., scale 1:1,000,000 (1" = 17 miles), UGMS Open-File Report 108. This report was revised in September, 1988 from the June, 1987 version and is in the process of being digitized for computer updating (see the lead article in this issue). The title Radon Death Map is ONLY in reference to the people who have to keep updating and redrafting it.

The art of geology, edited by E.M. Moores and F.M. Wahl, Geological Society of America Special Paper 225, 140 p., 1988. The GSA 1988 Centennial brought about a great many things. One was this publication — an unusual departure for GSA, the coffee-table book. Sooner or later, everyone connected with geology has a collection of rocks and photos in their desk (or garage), often as memorabilia, but sometimes purely for the beauty. These are not often shared; geologists tend to the non-sentimental and the nontalkative. This volume, then, represents two things for me: the latent desire (many of us have it) to publish photographs showing geologic beauty, and a sharing among friends of a loose-knit group who try to express how they feel about a profession and a subject.

All photographs were taken by working geologists (hence the incredible proliferation of rock hammers and pens growing in rock), mostly to detail a structural or stratigraphic event. The text is minimal and oriented to non-geologists; the design is exceptionally good, the dust jacket is award level.

The book goes far in explaining why geologists can look at a formation long after they finish the equally fascinating mental scramble of seeing how it got there. We are personally interested in the book for the inclusion of several shots by Grant Willis, UGMS Mapping Section, and for all the shots of Utah geology. Well done.

Physical, soil, and paleomagnetic stratigraphy of the upper Cenozoic sediments in Fisher Valley, southeastern Utah, by S.M. Colman, A.F. Choquette, and F.F. Hawkins, 1988, 33 p.: U.S. Geological Survey Bulletin 1686.

Mineral resources of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado and Daggett County, Utah, by J.J. Connor and others, 1988: U.S. Geological Survey Bulletin 1714-B.

Mineral resources of the Black Ridge Canyons Wilderness Study Area, Mesa County, Colorado and Grand County, Utah, and Westwater Canyon Wilderness Study Area, Grand County, Utah, by R.P. Dickerson, J.E. Case, H.N. Barton, and M.L. Chatman, 1988, 24 p.: U.S. Geological Survey Bulletin 1736-C.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Cottonwood Canyon Wilderness Study Area, Washington County, Utah, by D.E. Detra, J.E. Kilburn, J.L. Jones, and D.L. Fey, 16 p., 1 pl., 1988: U.S. Geological Survey Open-File Report 88-274

Selected hydrologic data for Pahvant Valley and adjacent areas, Millard County, Utah, 1987, by S.A. Thiros, 151 p., 1988: U.S. Geological Survey Open-File Report 88-195.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Steep Creek Wilderness Study Area, Garfield County, Utah, by R.T. Hopkins, R.J. Goldfarb, S.C. Rose, and R.B. Vaughn, 14 p., 1988: U.S. Geological Survey Open-File Report 88-208.

Analytical results and sample locality map of stream-sediment, heavy-metal-concentrate, and rock samples from the Cockscomb and Wahweap Wilderness Study Areas, Kane County, Utah, by D.E. Detra, J.E. Kilburn, J.L. Jones, and D.L. Fey, 28 p., 1988: U.S. Geological Survey Open-File Report 88-368.

The laccolith-stock controversy; new results from the southern Henry Mountains, Utah, by C.B. Hunt, M.D. Jackson, and D.D. Pollard: Geological Society of America Bulletin, v. 100, no. 10, 1988, p. 1657-1659.

Sediment-yield history of a small basin in southern Utah 1937-1976; implications for land management and geomorphology, by J.B. Laronne and Richard Hereford, 1988: Geology v. 16, no. 10, p. 956-957.

Seismic exploration of the crust and upper mantle of the Basin and Range Province, by L.C. Pakiser, 1985: Geological Society of America Centennial Special Volume 1, p. 453-469.

Diagenesis and burial history of nonmarine Upper Cretaceous rocks in the central Uinta Basin, Utah, by J.K. Pitman, K.J. Franczyk, and D.E. Anders, 1988: U.S. Geological Survey Bulletin 1787-D, p. 1-24.

Hydrocarbon potential of nonmarine Upper Cretaceous and lower Tertiary rocks, eastern Uinta Basin, Utah, by J.K Pitman, D.E. Anders, T.D. Fouch and D.J. Nichols, 1986, *in* C.W. Spencer and others, editors, Geology of Tight Gas Reservoirs: AAPG Studies in Geology 24, p. 235-252.

Seismicity map of North America, by E.R. Engdahl and W.A. Rinehart, 1988, scale 1:5,000,000: Geological Society of America Continent-Scale Map 4. The southwest sheet (sheet 1) covers the western U.S. and affords an overview of seismic trends.

Sequential development of a frontal ramp, imbricates, and a major fold in the Kemmerer region of the Wyoming thrust belt, by J.G. Delphia and E.G. Bombolakis, 1988, *in* G. Mitra and S. Wojtal, editors, Geometriews and Mechanisms of Thrusting, with Special Reference to the Appalachians: Geological Society of America Special Paper 222, p. 207-222.

Ground-water resources of the central Wasatch front area, Utah, 1988, by Don Price, 3 plates, 5 page report, scale 1:100,000, UGMS Map 54-C. This is one of a series of maps describing the geology, natural resources and hazards along the Wasatch front. This non-

Continued on next page.

technical report examines the occurrence, availability, and quality of ground water in the bedrock of the Wasatch Mountains and basin fill of the Salt Lake and Tooele Valleys. Discussions and schematic diagrams map the general direction of ground-water flow in the area as well as the dynamics of recharge and discharge of ground water. The map is presented in three plates. Plate 1 shows saturated thicknesses and transmissivity (rate at which water moves through a unit width of an aquifer under a unit hydraulic gradient) of the altitude of potentiometric surfaces from the spring of 1965 to the spring of 1980. Plate 3 delineates the general quality of water in the basin fill and areas of thermal ground water.

Geologic Map of the Thatcher Mountain Quadrangle, Box Elder County, Utah, 1988, by Teresa E. Jordan, Max Crittenden, Jr., Richard W. Allmendinger, and David M. Miller, 2 sheets, 10 page report, scale 1:24,000, UGMS Map 109.

Geologic Map of the Howell quadrangle, Box Elder County, Utah, 1988, by Teresa E. Jordan, Richard W. Allmendinger, and Max D. Crittenden, Jr., 2 plates, 10 page report, scale 1:24,000, UGMS Map 107. Both the Howell and Thatcher Mountain quadrangles are located in northwestern Utah, north of the eastern arm of the Great Salt Lake and less than 10 miles south of the Utah-Idaho border. Dominant topographic features in the study areas include Anderson Hill and Blue Creek Valley in the center, the Blue Springs Hills along the southeast corner, and the West Hills on the northeastern border. The north-south-trending Basin and Range mountains display Mesozoic folding and thrusting, and Cenozoic high- and low-angle faults.

These maps describe the stratigraphic and structural relationships of the Blue Springs Hills and adjoining North Promontory and Promontory Mountains and West Hills. They are part of a series of studies designed to investigate the evolution of the Paleozoic Oquirrh basin and its relationships to Mesozoic and Cenozoic deformation in northern Utah. Current research shows shows rapid thickness changes in the margins of the Oquirrh basin.

The oldest rocks found in the Thatcher Mountain quadrangle are Pennsylvanian Oquirrh Formation sediments. Lithologic characteristics of these and local Permian rocks indicate deposition in the shelf area of the northeastern basin.

The oldest exposed rocks in the Howell quadrangle are Mississippian-Pennsylvanian Manning Canyon Shale sediments. Lithologic characteristics of these and other Paleozoic rocks indicate deposition in the shelf area of the northeastern edge of the basin. Cenozoic rocks include Tertiary sediments and Quaternary alluvium, colluvium, lacustrine and landslide deposits. In addition to structure and stratigraphy, the reports discuss known and potential economic deposits and geologic hazards.

The ***1989 List of Publications*** is now available from the Idaho Geological Survey, Morrill Hall room 332, Univ. of Idaho, Moscow, ID 83843 free of charge.

UGMS Staff

Cory Burt, our digitally dextrous program perverter has opted for the Department of Business Regulation, thereby leaving us menu-dependent types in a quandry.

Marge Porterfield consented to be the new secretary for Mapping and Economic sections while *Cheryl Crockett* has joined us in the new Sales position. Cheryl worked under our former accounting officer, Gwen Anderson, and probably should have been forewarned. Marge's previous experience includes teaching, real estate development, insurance and securities sales, and considerable environmental community involvement.

Archie Smith served as the head of the Economic Section and as the UGMS industry liaison, but has decided to work with his son-in-law as Executive Vice-president of Transoft International; he's obviously excited about all the possibilities, but he plans to keep up his contacts in all aspects of coal.

Our Sample Librarian, *Carolyn Olsen,* has returned with a set of crutches and her old sense of humor from a very serious car accident. She has help with the boxes of core from our new part-timer *Tom Rahn.*

Susan Olig, the new geologist in Applied Section, is finishing up her Masters in structural geology at the University of Utah. She has worked for Dames & Moore as a geologist, primarily investigating seismic hazards. Susan enjoys skiing, gardening and hiking.

Five-year service awards were presented to three UGMS staffers during our last staff meeting. Each received a plaque set in a polished section of variscite, one of the gemstone commodities of Utah. Congratulations to:

Kent Brown, Senior Cartographer, who began in June, 1983;
Ray Kerns, Energy Geologist, who came on in January, 1983;
and to *Grant Willis,* Geologic Mapper, who started in July of 1983.

New Publications From The UGMS

— The latest publications catalog is available upon request—

Geology of the Bear River City quadrangle, Box Elder County, Utah, by M.F. Jensen, 42 p., 1 pl., Open-File Report 145, available for inspection at the UGMS Library.

Geology of the Gunnison quadrangle, Sanpete County, Utah, by S. R. Mattox, 39 p., 2 pl., Open-File Report 146, available for inspection at the UGMS Library.

MINERAL LEASE SPECIAL PROJECTS PROGRAM

by
Douglas A. Sprinkel

The Utah Geological and Mineral Survey (UGMS) formulated a new program in the early part of 1987 which would solicit proposals from the scientific community for geologic projects that would produce publishable results through the UGMS. The Mineral Lease Special Projects Program (MLSPP) was implemented during spring of 1987 with the appropriate approval and the initiation of the first round of informal solicitations. The proposals received competed for funding on geologic merit, expertise of the proposer, and importance to Utah. They were funded from UGMS' budget with mineral lease revenues.

Two rounds of informal solicitation for proposals have been completed with the awarding of 22 contracts for a variety of geologic projects. The first round was held in spring of 1987 followed by a second round in January 1988. Now that the third round of informal solicitation for proposals is underway, it seems appropriate to reflect on the past two cycles and assess the effectiveness and direction of the program.

PURPOSE OF THE MINERAL LEASE SPECIAL PROJECTS PROGRAM

The Mineral Lease Special Projects Program was conceived by Genevieve Atwood (Director, UGMS) and Don Mabey (former Deputy Director, UGMS), at the urging of the UGMS Board, as a means to contract for special types of geologic information which supplemented continuing UGMS programs without adding permanent staff. It has proven to be a great opportunity to advance the ongoing progress of the UGMS mission. The basic objectives of the program are stated in table 1. However, the general purpose of the program is twofold; to acquire new geologic information and to provide a means of accessing existing geologic data and information that would otherwise be lost.

The funding available for the contacts will vary each round. The UGMS depends on a variety of revenue sources to fund its operations and programs. All expenditures are authorized yearly by the Utah State Legislature. State revenues appropriated are generally fixed amounts with the exception of mineral lease funds. These funds are payments made by the mineral industry to the federal government for exploration and production on federal leases within the state. The UGMS receives 2.25 percent of what the state receives. These revenues oscillate as much as 25 percent in a year as production and exploration levels in Utah vary and prices of energy and mineral commodities fluctuate. Prior to about 1982, prices and production of energy resources in the state appeared fairly predictable, permitting the state to forecast with some certainty what mineral lease revenues would be for the upcoming fiscal year. However, with the collapse of oil prices and the subsequent shift away from domestic exploration, the state's financial prognosticators have difficulty in forecasting meaningful revenue estimates and the UGMS management could not adjust expenditures to match revenues particularly when the actual revenues were not known until after the end of the fiscal year. The Mineral Lease Special Projects Program doesn't change the revenue fluctuations, but serves to minimize the impact of the fluctuation on the management of the UGMS program. The result is a pool of funds, which is not known until the end of the fiscal year, available for special mineral lease contracts.

The primary purpose of the program is to obtain geologic data and information from individual scientists and organizations who have invested time and money in geologic investigations in Utah, but have not made the results of these investigations available to the public. It also creates an opportunity for some timely new research in Utah. This is in accordance with the mission of the UGMS which is to inventory the geologic resources of Utah; identify the state's geologic hazards; better understand Utah's geology through mapping of rock formations and their structural habitat; and disseminate geologic information to teachers, decision makers, state and local governments, and the general public in a way that the information will get used. The Mineral Lease Special Projects Program provides the necessary incentive to get existing and new ideas and data published. The UGMS believes this is an innovative way to obtain and make data, information, and ideas on Utah's geology available to the public through publications at a much reduced cost to Utah.

OBJECTIVES OF THE MINERAL LEASE SPECIAL PROJECTS PROGRAM

(1) Engage expertise not currently available in the UGMS.
(2) Build upon the expertise of individuals within the earth science community who have devoted years to understanding certain geologic problems or geographic areas of the state; thereby acquiring information that has the potential of being lost or for a price below what it would cost to acquire it using UGMS staff.
(3) Obtain specific geologic information in neglected areas of the state, or areas not fully understood or not presently being investigated by UGMS staff.
(4) Undertake important short-term projects without increasing UGMS staff.

Table 1. *Objectives of the Mineral Lease Special Projects program.*

HOW THE PROGRAM WORKS

The UGMS has four scientific programs whose mission is to study and report on Utah's geologic resources (Economic Geology Program) and geologic hazards (Applied Geology Program), better understand Utah's geologic rock units and their history through regional and detailed mapping (Mapping Geology Program), and provide basic geologic information for the general public (Information Program). The emphasis placed on geologic topics can change with each round of informal solicitations. It can be directed at projects specifically related to one of UGMS' geologic programs or include a variety of projects from each program depending on current need or area of interest of the state. The UGMS Management Advisory Group (composed of the UGMS Director, Deputy Director, Special Assistants to the Director, and Geologic Managers) with the advice from the UGMS Board determines the emphasis for each round of informal solicitations, generally in November. They also decide on several topics for geologic projects based on suggestions from the UGMS geologists. These topics usually reflect areas where geologic data has been collected but not released for public use. They also may reflect areas where additional information is needed and not currently being investigated by the UGMS.

An informal solicitation for proposals document is prepared and distributed in January. Proposals are prepared under guidelines provided in the solicitation and may be received by the UGMS until the closing date which is generally in March. Each proposal is reviewed and rated by three UGMS geologists. The proposal reviews and ratings are compiled and the proposals are ranked in April by the UGMS Management Advisory Group. The recommended ranking is presented to UGMS Board in early May, and the Board selects the proposals that will receive funding.

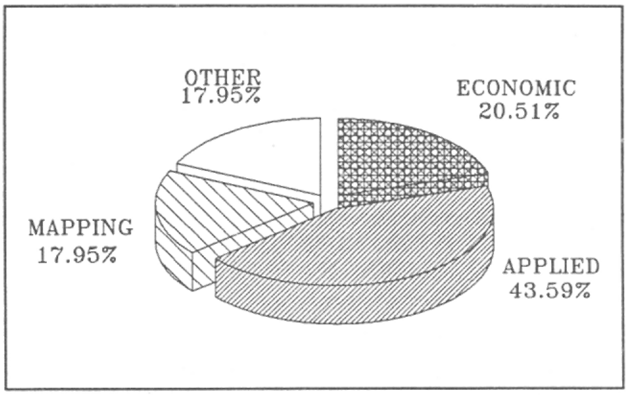

Figure 1. Percentage of proposals received in 1987, by UGMS program.

1987 INFORMAL SOLICITATION FOR PROPOSALS

The 1987 cycle was the first round for the proposals and the UGMS had considerable uncertainty concerning the number and type of response to the solicitation. To encourage as many proposals as possible for this first round, UGMS offered a wide variety of topics in all UGMS programs.

A total of 39 proposals received in 1987 represented a combined amount of about $407,500. The average amount for a proposal was about $10,500. The majority of proposals received were on topics relative to the UGMS Applied Geology program (figure 1). The affiliations of the proposers submitting proposals in 1987 included the academic community, private sector, and governmental agencies. Most of the proposals submitted were from investigators in the academic community (figure 2).

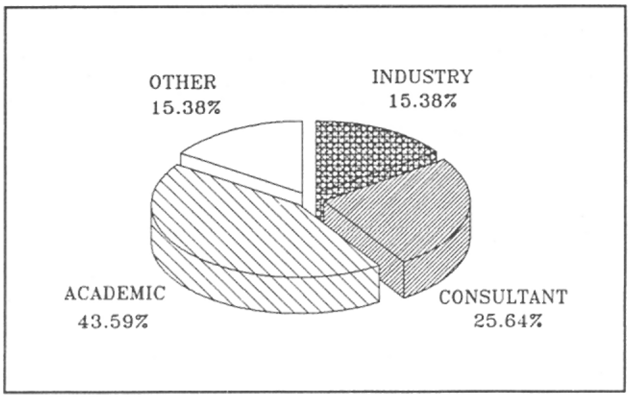

Figure 2. Percentage of proposals received in 1987, by proposer's affiliation.

Out of the 39 proposals submitted, 10 were funded for a total cost of $96,072. The smallest proposal funded was $1,320 and the largest was $16,640 with the average proposal amount being $9,607. Table 2 summarizes the proposals funded in 1987. As noted in table 2, several investigators have completed and submitted their contract products. These products are generally manuscripts, maps, or both which will be published by UGMS as a Miscellaneous Publication (MP publication series) or released to the public as an open-file report (OFR series). The remaining contracted products are expected to be completed and delivered to UGMS sometime during the current fiscal year.

In the 1987 round, the stronger proposals suggested projects to identify geologic hazards or better understand geologic hazard processes. Most were related to earthquake research. Consequently, the majority of funding went to projects dominantly related to UGMS' Applied Geology Program (figure 3). Other proposals funded were projects intended to provide geologic information for the educational community (figure 3). No proposals of a strictly economic geology nature were funded in this round (figure 3).

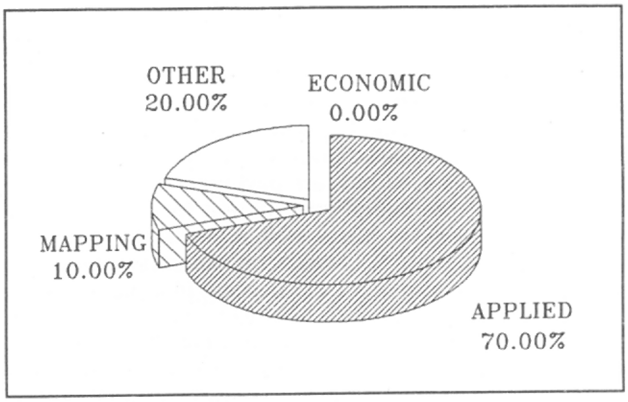

Figure 3. Percentage of proposals funded in 1987, by UGMS program.

Table 2. List of proposal funded in 1987

ML SPECIAL PROJECT TOPICS FUNDED IN 1987.

Modeling of structural and earthquake characteristics of the southern Wasatch fault zone.
R.L. Bruhn; University of Utah

Catalog of Utah metallic ore milling sites.
L.P. James; Consultant

Radiometric dating and correlation of volcanic ash beds of part of the Mesozoic Era.
*B.J. Kowallis; Brigham Young Unversity***

Utah geologic hazards teachers workshop.
*E.H. O'Brien; Utah Museum of Natural History**

Response of collapsible soils to earthquake shaking.
*K.R. Rollins; Brigham Young University**

Subsurface map and seismic risk analysis of the Salt Lake Valley.
*G.T. Schuster, University of Utah**

Geometry and kinematics of normal faults in Utah from seismic reflection data and analytic modeling.
R.B. Smith and H.M. Benz; University of Utah

Use of computer linked remote weather stations to determine the relationship of weather events to slope failures in Davis County, Utah.
*M. Lowe and others; Davis County Flood Control**

A short course in petroleum geology, with examples from Utah's petroleum provinces.
*C.N. Tripp; Consultant**

Liquefaction severity index and hazard map for Utah.
*M.A. Mabey and L. T. Youd; Brigham Young University**

** Indicates delivery of contracted products*
*** Indicates partial delivery of contracted products*

Most of the proposals funded in the 1987 round were from investigators from the academic community with considerable experience and skill in preparing proposals (figure 4). A distant second were proposals submitted by the consulting community in the private sector and others in local governmental and quasi-governmental organizations (figure 4). The UGMS and the UGMS Board were quite satisfied with the overall results of the 1987 Informal Solicitation for Proposals. The response to the solicitation was greater than anticipated and the quality of most proposals submitted was generally high. Having completed the first round successfully, the UGMS and its Board were eager to begin preparing the 1988 round of informal solicitations and get the Mineral Lease Special Projects program on a regular schedule and formalize the process.

1988 INFORMAL SOLICITATION FOR PROPOSALS

Little modification was incorporated into this cycle. Most of the changes were procedural in nature and went generally undetected outside the UGMS. Some changes were made to ensure internal compatibility with other UGMS programs and policies. The UGMS decided for the 1988 round to not consider proposals submitted by investigators employed with other Utah state agencies and federal agencies where they have existing cooperatives or contractual programs with the UGMS. In addition, guidelines and policies of existing internal programs were incorporated into the 1988 round, such as restricting any multipurpose mapping proposals to a $1,500 cost and discouraging costly proposals over $20,000, to minimize any repercussions or conflicts with other contracting programs in the UGMS.

The UGMS and the UGMS Board were somewhat disappointed by the small response to the solicitation from industry in 1987. They were even more disappointed and concerned that virtually no proposals were funded in 1987 for projects of an economic geology nature. To prevent repetition in 1988, the UGMS and the Board specifically targeted proposals that addressed areas of economic geology in Utah. All proposals submitted to UGMS would be considered, but it was made clear in the solicitation that proposals which addressed targeted topics would receive special consideration.

The Informal Solicitation for Proposals was prepared and distributed in January. The UGMS received 41 proposals by the closing date of March 18, 1988. The sum of all proposals received by the UGMS was about $375,000 in 1988 with the average submitted proposals being about $9,100. Each proposal was independently reviewed by three UGMS geologists and returned to the UGMS Management Advisory Group by the end of April for consideration. The ranked proposals were submitted to the UGMS Board in early May and the top-rated proposals were selected for funding.

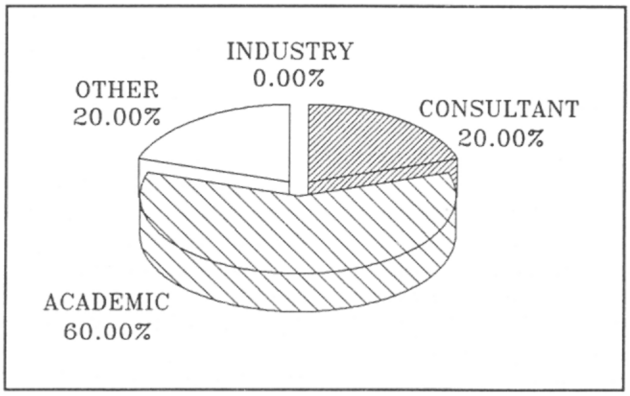

Figure 4. Percentage of proposals funded in 1987, by proposers affiliation.

The proposals the UGMS received in the 1988 round again encompassed a wide variety of topics. However, this time the majority of proposals offered projects of an economic geology nature (figure 5). Most of the projects related to economic geology proposed to investigate the location and geologic habitat of mineral commodities in Utah. Many intended to identify and inventory certain commodities. Others defined the geologic parameters responsible for an occurrence and discussed areas of potential based on observations. A number of proposals offered would provide an insight into Utah's subsurface using well control or the aid of information obtained from geophysical investigations. These proposals intended to define subsurface geometries and geologic relationships which may suggest areas for future exploration. Although these kind of investigations are extremely important to Utah, most of them were not funded because the basic data (seismic lines, gravity data, etc.) to derive interpretations would not be made available to the UGMS to publish. One of UGMS's goals is to prevent the unnecessary loss of valuable data by collecting and being the repository of geologic (and geophysical, geochemical) data in Utah. Hopefully future proposals will indicate these kinds of data will be a part of the proposed products.

The affiliation of proposers submitting proposals once again represented members of the academic community, private sector, and governmental and quasi-governmental organizations (figure 6). Similar to the 1987 round, nearly half of the proposals received by UGMS were generated by members of academia.

Out of the 41 proposals submitted to UGMS, 12 were funded in 1988 for a total of about $106,200. The smallest proposal funded was $4,060 and the largest was $17,500 with the average proposal amount being $8,850.

The emphasis of the 1988 round of informal solicitations was on projects related to economic geology which may lead to economic development of an area in Utah. UGMS and the Board members were diligent in awarding funds to those kind of projects. Figure 7 summarizes the proposals funded in 1988 with about two-thirds of the available funding going to projects that reflect this emphasis. Table 3 summarizes the proposals funded in 1988. From the topic descriptions, there appears to be a fairly even split between petroleum-related and mineral-related projects. All of these projects will contribute important concepts concerning their areas of interest and will add significant data to the state's information base.

The distribution of the proposer's affiliation for the funded projects somewhat mimicked the results of the 1987 round. However, the 1988 round was more successful in attracting proposals from industry. Although a large percentage of funds went to individuals from academia, followed by members of the consulting community, UGMS was able to award a contract to an individual from industry (figure 8). No funds were awarded to proposals that came from governmental or quasi-governmental organizations.

The 1988 round of Informal Solicitation for Proposals was an improvement over the 1987 round in several respects. The timing for future solicitations was established. Modifications in the solicitation and the review process were incorporated that improved the methodology of the selection process. The UGMS received more proposals and funded more projects than in 1987. Finally, the projects funded were directly related to the kind of projects UGMS felt would be important contributions to the state and could possibly initiate economic development in certain areas of Utah.

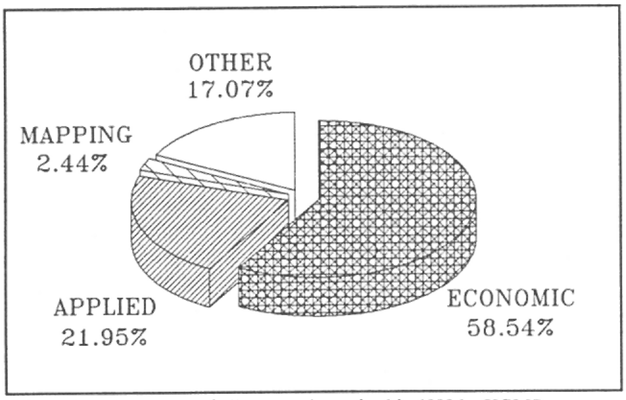

Figure 5. Percentage of all proposals received in 1988 by UGMS program.

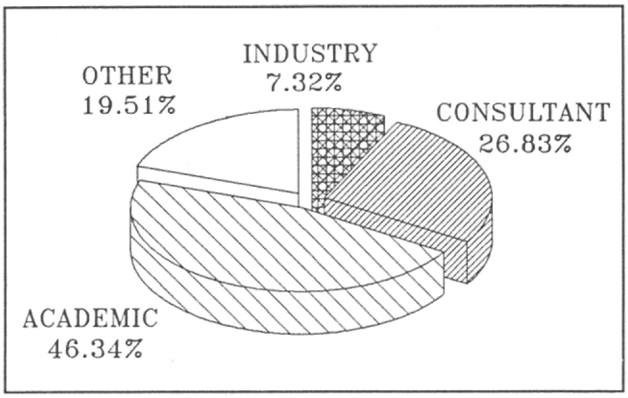

Figure 6. Percentage of all proposals received in 1988 by affiliation.

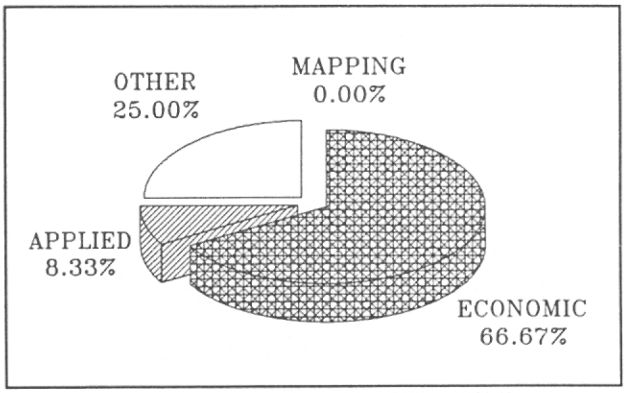

Figure 7. Percentage of proposals funded in 1988 by UGMS program.

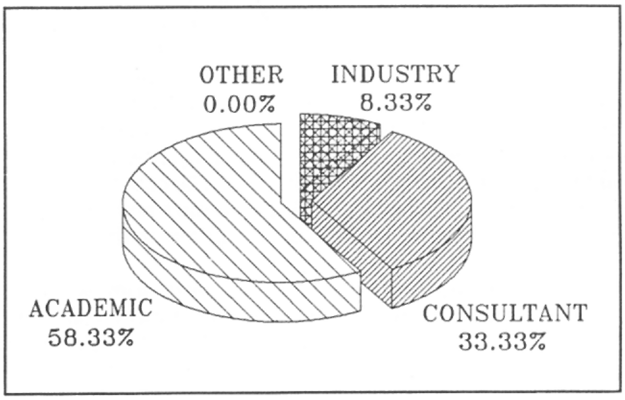

Figure 8. Percentage of proposals funded in 1988 by affiliation.

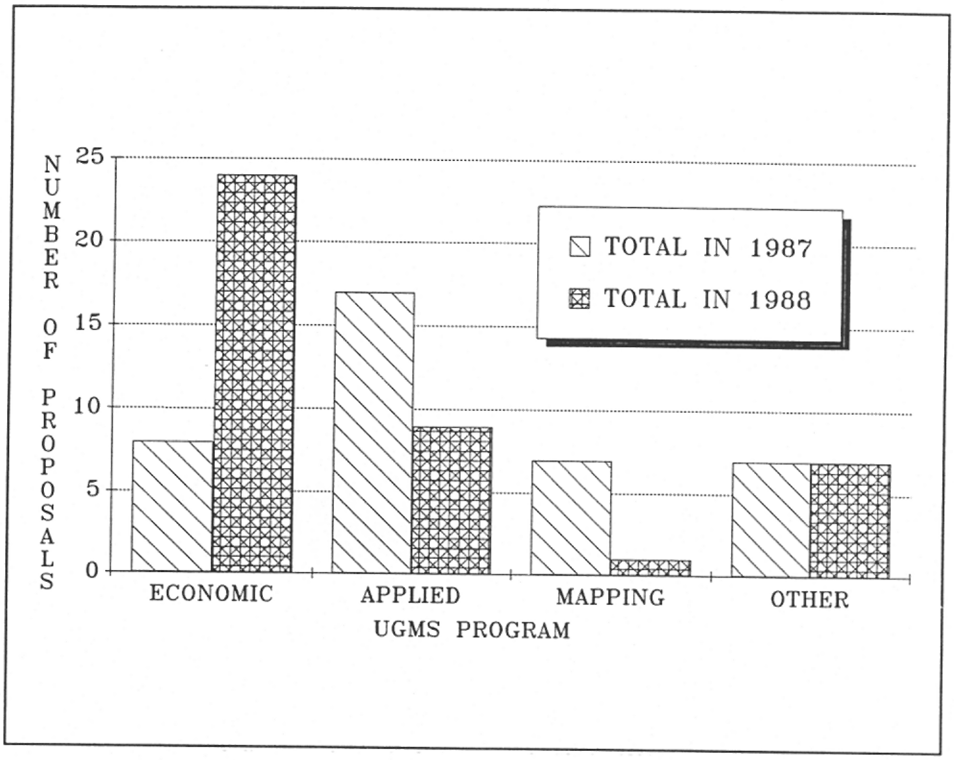

Figure 9. Comparison of all proposals received in 1987 and 1988 by UGMS program.

Table 3. List of proposals funded in 1988.

1988 ML SPECIAL PROJECTS TOPICS

Eocene-Oligocene history of the East Tintic Mountains, Utah.
J.D. Keith and R.D. Dallmeyer; University of Georgia.

Mineral chemistry of the Beryllium/Yttrium-rich Sheeprock Granite of western Utah.
E.H. Christiansen; Brigham Young University

Dating methods applicable to Quaternary geologic problems in the western U.S.A.
S.L. Forman and G.H. Miller; University of Colorado

A hydrocarbon exploration model (Ferron & Dakota Sandstones) on the Wasatch Plateau, Utah.
C.N. Tripp; Consultant

Petroleum source-rock evaluation.
D.S. Chapman and D. Deming; University of Utah

Geochemical characteristics of black shales related to Mercur-type gold deposits.
W.T. Parry and P.N. Wilson; University of Utah

Oil development and potential of Mississippian formations, San Juan County, Utah.
H.W. Merrell; Consultant

Yttrium resources in Utah.
W.P. Nash; University of Utah

Uranium deposits and potential uranium resources in Grand County, Utah.
H.W. Merrell and W.D. McDougal; Consultant

Potential stratigraphic traps from landward pinch-outs of Cretaceous shoreline facies, Book Cliffs-Wasatch Plateau.
P.B. Anderson; Consultant

Thin-skinned deformation mechanisms of Wasatch Plateau area, Utah.
G.L. Hunt; Cyprus-Plateau Mining

Characterization of ground-water flow systems as related to the proposed "Super Tunnel."
A.L. Mayo; Brigham Young University

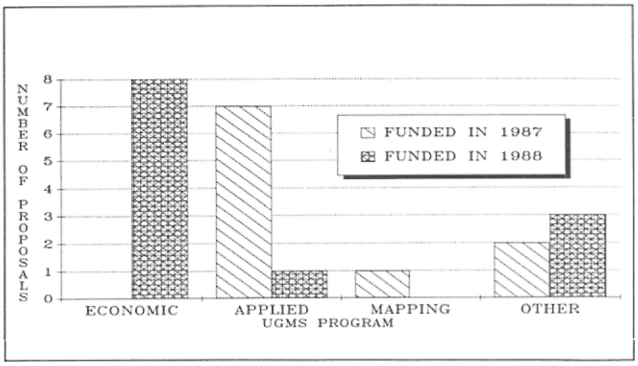

Figure 10. *Comparison of proposals funded in 1987 and 1988 by UGMS program.*

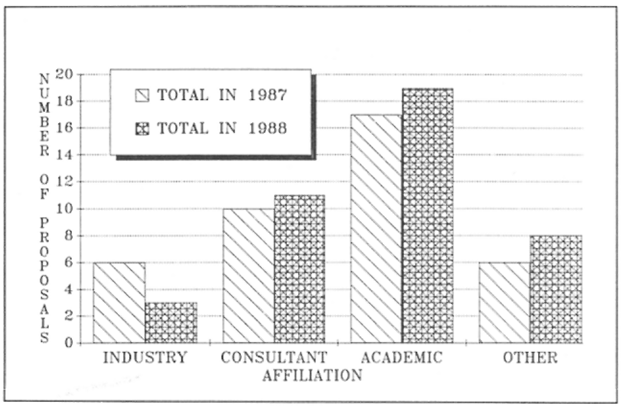

Figure 11. *Comparison of all proposals received in 1987 and 1988 by proposer's affiliation.*

COMPARING THE 1987 AND 1988 ROUNDS

The two rounds of informal solicitations were similar with respect to the number of proposals received, the number of proposals funded, the amount of funds available, and who submitted proposals. The differences between the two rounds directly reflect the change in the UGMS emphasis from one cycle to the next. These changes are mostly related to the kind of projects that will produce information and data which satisfy current needs of the state.

In 1987, most of the proposals received were projects related to UGMS Applied Geology Program, whereas in 1988 the kind of proposals received were dominated by projects related to the Economic Geology Program (figure 9). Because the UGMS indicated that economic geology-related proposals would receive special consideration, the proposers responded accordingly. It is interesting to note that the number of proposals that fell into the "OTHER" category was the same and the Mapping (Mapping Geology Program)-related proposals fell off significantly. The difference in the number of mapping-related projects probably reflects the reduction of award amounts for mapping projects to make them consistent with the existing contracts in the multipurpose mapping program.

A comparison of proposals funded by UGMS program generally reflects the pattern of the relative number of proposals received for that solicitation cycle. Most of the proposals funded in 1987 were related to the Applied Geology Program, and in 1988 the funds generally went to proposals related to the Economic Geology Program (figure 10).

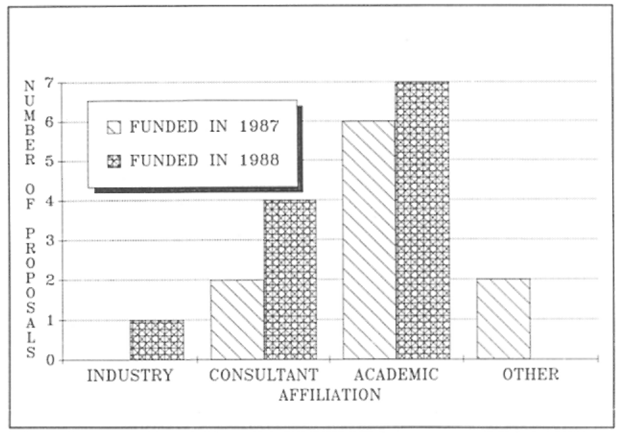

Figure 12. *Comparison of all proposals funded in 1987 and 1988 by proposer's affiliation.*

A comparison of the proposer affiliation in 1987 and 1988 reveals that the proposer types were represented in about the same relative numbers. Both rounds were dominated by proposals submitted by individuals from the academic community followed by the consulting community (figure 11). A similar pattern emerges with a comparison of proposer's affiliation who received funding in 1987 and 1988 (figure 12). A notable difference is the decrease in the number of industry projects funded in the 1988 round.

CONCLUSIONS

The first two rounds of informal solicitations met or exceeded UGMS expectations. This procedure has proven to be an effective way to obtain and disseminate existing and new geologic data pertaining to Utah. UGMS is confident that much of this information would not get published soon, if ever, without the small amount of funding this program provides. The Mineral Lease Special Projects Program also provides for more effective management of the UGMS budget. Most all of the proposals received by UGMS in these first two rounds have been strong proposals, thereby making the job of the UGMS and the Board members a difficult one in selecting the top proposals for the funding.

Now that the next cycle of Informal Solicitation for Proposals is in progress, the UGMS can look back at the 1987 and 1988 cycles and apply much of what was observed to the 1989 cycle. UGMS expects the funds available for the 1989 round will be roughly the same as the past two rounds, about $100,000. The UGMS also expects to fund about the same number of proposals (10 to 15) depending on the size of the individual proposals submitted. The 1989 round will consider all topics in geology equally (topics in economic geology, applied geology, etc.) and hopefully will fund proposals from each of the related programs of the UGMS. To add your name for future mailings of the Informal Solicitation for Proposals for Geologic Projects, contact the Utah Geological and Mineral Survey.

PROPOSALS
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

Utah Conference on the Potential Indoor Radon Hazard

Wednesday, June 21, 1989
State Office Building Auditorium
8 a.m. to 5 p.m.

Sponsored by the Utah Geological and Mineral Survey, the Utah Bureau of Radiation Control, and the University of Utah Research Institute.

CANCELLED

Objective

This conference will provide a forum for public education by presenting a non-technical overview of current radon research. Topics will emphasize factors affecting Utah and the Rocky Mountain region. Major topics to be considered will include a definition of the basis for current concern, and will trace the course of public and professional involvement from detection of the potential hazard through prevention or mitigation.

Scope

A 1-day symposium will be held in Salt Lake City in mid-June, 1989. The audience will be drawn primarily from the non-technical public of the Wasatch Front region who desire to obtain more information on this recently publicized potential health hazard. Admission will be free, but a modest charge will be made for a volume of symposium talks.

1989 USGS McKelvey Forum

Nearly 800 scientist and explorationists attended the Fifth Annual V.E. McKelvey Forum on Mineral Resources held in Reno, Nevada, January 24-26, 1989. The forum consisted of 26 oral and 66 poster presentations of current research activities by USGS scientists and co-workers. The presentations covered a broad range of topics in economic geology with a strong emphasis on gold deposits of the Great Basin. Abstracts of these presentations are available in U.S. Geological Survey Circular 1035. The UGMS, represented by John Hand and Mike Shubat, contributed to two of the poster sessions, which presented results of the Delta CUSMAP project and the Tooele Preassessment project.

GREAT SALT LAKE LEVEL

Date (1986)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Nov 01	4206.60	4205.65
Nov 15	4206.50	4205.60
Dec 01	4206.50	4205.60
Dec 15	4206.45	4205.60
Jan 01	4206.45	4205.65
Jan 15	4206.45	4205.70
Feb 01	4206.50	4205.70
Feb 15	4206.50	4205.75

Source: USGS provisional records.

UTAH DEPARTMENT OF NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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